Case for New Zealand Membership of the International Partnership for Geothermal Technology

Prepared by

Brian White
Executive Officer, New Zealand Geothermal Association
and
Commercial Development Manager, East Harbour Energy Ltd

With the assistance of the New Zealand geothermal community

23 August 2011

Table of Contents

1. Introduction

The New Zealand Government is seeking to join the International Partnership for Geothermal Technology (IPGT) and has publicly announced this intention. Target date for joining is at a meeting in November 2011, with a signing ceremony to be held in conjunction with another meeting in Australia at that time.

The documentation is to include an information packet. The following is extracted from the IPGT website on requirements:

> *"A complete application packet should include, along with a letter of intent, documentation attesting to active (1) government and (2) private-sector involvement in advanced geothermal technologies. Additionally, the country should attach an assertion of its willingness to share information with the other IPGT member countries. The SC will use the application packet to evaluate the contribution that an applicant can be expected to make to the IPGT and to ensure sufficient involvement in the geothermal sector. Please tailor contributions to these criteria.*
>
> *Please specify the type of R&D and specific projects, either underway or planned, in your country. Provide as much information as possible, including: detailed project description; investment sources and amounts; involved parties and industry partners; timeline; and the current status and stage of each project.*
>
> *Information should also be included on: the nature and monetary value of government support for geothermal technologies; a description of the agencies involved in geothermal development in the country; the leasing procedures; relevant policy initiatives; any applicable incentives (and their longevity); geothermal education support and initiatives; and the cost of electricity (commercial, residential and industrial).*
>
> *Additionally, please provide information on ongoing conventional and advanced geothermal activities including (all that are applicable): MW produced; site name and location; stage of development (if not completed); number of wells; well depth; well temperature; flow rate; reservoir capacity; formation details; type of technology (and brand) used; power plant type; current capacity and plan for expansion.*
>
> *Finally, describe the landscape of the geothermal industry and support industries in your country. Include the number of companies involved; whether they are publicly traded and how long they've been in existence; the level of investment; and a description of the relationship between government and industry."*

The following document sets out a response to the information request.

Note that at the heart of New Zealand's application is an international reputation based on sixty years of large scale research and development of geothermal projects for both heat and electricity. New Zealand geothermal scientists, engineers and researchers continue to have a major influence on high temperature developments domestically and internationally, are now extending their interests and can make useful contributions to international debates and research. In terms of numbers of personnel, there is a critical mass that ensures ongoing activity and interest. In terms of outlook, the New Zealand geothermal community has always had an outward vision. The Government is supportive of this industry and wants to see both New Zealand and international geothermal interests at the leading edge of geothermal development.

2. *The Landscape for the New Zealand Geothermal Industry Including Agencies and their Respective Roles*

This will cover the number of companies involved, whether they are publicly traded and how long they have been in existence, the level of investment, description of the relationship between government and industry. It will also cover the cost of electricity (commercial, residential and industrial). More details on the various industry participants are given in Appendix 1.

2.1 The Major Participants

Historically, in the 1950's and 60's New Zealand led the world in the research and development of water-dominated geothermal systems. Much of this early work was undertaken by government scientists and engineers, working in parallel with an English engineering consultancy (Merz and McLellan). During this period major developments were undertaken at Wairakei and at Kawerau, but exploration was also undertaken at Waiotapu, Ngawha, Tauhara, Broadlands, Orakei Korako, Te Kopia, Rotokawa and Reporoa. Engineers with the Ministry of Works developed geothermal drilling techniques and developed the separators which enabled global uptake of geothermal development. Further research was done by the Ministry of Works and by the Dominion Physical Laboratories on two-phase flow. The Department of Scientific and Industrial Research (the Crown's research agency) undertook foundational research on geophysical techniques, heat flow measurements, geothermometers, fluid-mineral equilibria, etc then applied these techniques to fields under exploration and development. The Ministry of Works also helped with the development of initial legislation around geothermal energy while other parts of the Ministry eventually had regulatory functions in terms of geothermal approvals or approval of water rights. The Electricity Department operated and continued to develop Wairakei, building up experience and refining design.

In the 1970's, the Government of the day recognised that New Zealand had an exportable commodity in terms of the expertise associated with geothermal development and chose to engage in regional aid projects. Amongst these were projects in El Tatio (Chile – an investigation and drilling program), Kenya, Turkey and Mexico. Geothermal aid projects were initiated at Tongonan, Leyte, Philippines and Kamojang, West Java, Indonesia amongst other projects. The government specialist expertise was made available through a private company called Kingston Morrison for the Philippines and through a private joint venture known as Geothermal Energy New Zealand Limited (GENZL) for Indonesia and elsewhere. In turn, these companies and government agencies have continued to build and develop skills and geothermal expertise and have been active both domestically and internationally.

An extension of the NZ aid efforts came through the support of the establishment and ongoing operation of one of the worlds leading trainers of geothermal expertise through the Geothermal Institute within the University of Auckland. The Institute itself commenced service in 1979 continuing until 2002 when government support was withdrawn. The Geothermal Institute has now been re-established, again with government funding, but the University of Auckland has maintained active training and research programmes throughout this period to the present. One outreach of the Institute was the annual New Zealand Geothermal Workshop timed to coincide with the end of the university year. This has become an institution in its own right and has been held annually since 1979, including all recent years, making it one of the longest-running geothermal conferences in the World. Because of the international nature of the Institute, the Workshop proceedings have always strongly reflected international research and development projects.

From the mid-1970’s to the late-1980’s the government embarked on further national geothermal research programmes particularly aimed at potential developments at Broadlands/Ohaaki, Kawerau and Ngawha. Government efforts were also directed at wider exploration of the Taupo Volcanic Zone including regional resistivity and chemical surveys, backed up by drilling in ten other fields. This effort was terminated in 1988 for a variety of reasons. Among these was the presence of low cost gas from the Maui field that could undercut almost all other forms of electricity generation in terms of price, with that situation maintained until around 2003. Another major factor in the termination of the exploration programme was the view that government should not be directly involved in development. Major restructuring of former government departments and ministries took place, and greater emphasis was placed on asset divestment and contracting to private interests.

Simultaneously, New Zealand companies have been part of the international trend of mergers and acquisitions. The end result is a wide diversity of local companies and research groups that have stayed active in both local and international markets.

In the early days of geothermal development, some local electricity utilities known as Electricity Supply Authorities (ESAs) had an interest in geothermal development, investing in projects at Kawerau, Rotokawa, Ngawha and the Poihipi development on the Wairakei field. However, the ESAs were like the national electricity utility, having a mix of natural monopoly elements and competitive elements. Electricity reforms in the late 1990’s were initiated to separate these functions into separate companies, temporarily losing some of these investors from the geothermal scene. More recent reforms have relaxed some separation rules and seen reinvestment by what are now dominantly distribution line companies. Such companies include Top Energy and elements of the Eastland Group.

In setting a landscape of participants in the geothermal market place, obviously there are many landowners with an interest in geothermal energy. Maori Trusts are a special landowning interest in New Zealand. Traditionally, Maori land was owned collectively, so Trusts have been formed as the legal entity for the maintenance and development of these collectively owned assets managed on behalf of the beneficial owners. While much Maori land has been sold into private ownership, there are often ongoing land interests in the vicinity of geothermal features, because of strong cultural identification with the geothermal resource. Maori have used the geothermal resource for their own ends and, in a modern context, are equally open to sustainable development at a large scale, for electricity or heat, tourism or therapeutic reasons. Many geothermal developments today are being undertaken in joint venture with, or sole development by Maori Trusts.

Another set of participants in the geothermal scene is local government. In 1991 the Resource Management Act was passed with a view to collecting a large amount of resource development legislation under one unified act, in which decision making was devolved to regional and local governments. Under the Act, geothermal energy was treated like water, rather than a mineral. Most of the high temperature geothermal fields are found in the areas administered by the Bay of Plenty and the Waikato Regional Councils.

Through all of the development efforts now stretching over 60 years, local New Zealand companies have supported the domestic development efforts from design through manufacture to installation and servicing. These companies have included major civil engineering and heavy engineering companies. These companies have capabilities across all civil engineering aspects; manufacture of heat exchangers, pressure vessels, valves and pipe to various code requirements; and now include the ability to re-engineer some of the most complex items. In addition there have been the usual drilling support companies. Beyond this are a wide range of companies that are able to assist with environmental impact assessment and monitoring. The depth of capability they have developed has seen them become increasingly involved in export activity to the Asia Pacific region.

The following table sets out the genesis and activity of several of the major companies and agencies in the New Zealand geothermal market.

Table 1: Some major participants in the New Zealand geothermal scene

Company/Agency	Genesis	Activity and Notes
Government		
Ministry of Economic Development	Includes diverse government interests around economic development	In this context, includes elements of what would normally be done by a Ministry of Energy, including market monitoring and regulatory intervention when required. Because of the important role of energy to the economy, MED will typically have a supervisory role across other Ministries and Agencies where new policy or legislations affects energy
Ministry of Science and Innovation	This is a Ministry established in 2011, based largely on the Ministry of Research Science and Technology. In turn these evolved from science directive sections of the old Department of Scientific and Industrial Research	MSI is the New Zealand government's largest funder of geothermal research.
The Treasury	The Treasury is an obvious longstanding part of Government	In this case we note the presence of a Crown Ownership Monitoring Unit within Treasury, which reviews the performance of State-Owned Enterprises such as Mighty River Power and GNS Science to ensure that they are competently managed and operate on a level playing field with private sector in the same market. The Treasury still holds some geothermal wells and associated information following the disestablishment in the 1980's of the Ministry of Energy that had funded a Crown drilling programme. Some assets at Kawerau were transferred to a Maori entity through Mighty River Power as part of a recent Treaty settlement. Other wells may be available for Maori Trusts as part of future Treaty settlements.
Bay of Plenty Regional Council, Waikato Regional Council	While there have been forms of regional and local government from New Zealand's early colonial days, most councils formally came into existence in their current form with current boundaries in 1989 and were vested with additional responsibilities by the Resource Management Act 1991	These councils have administrative areas covering most of New Zealand's high temperature fields. They develop regional plans and policy statements to enabled ordered sustainable development of all resources within their boundaries. Applications for developments by the various developers are considered against these plans and policy statements, before consents are granted and conditions are set. Developers must then undertake developments in a compliant manner and report on their operations.
Electricity Generators and Lines Companies		
Contact Energy Ltd	At one stage all Electricity Department assets were brought together under the Electricity Corporation of New Zealand. Efforts to develop a market required competition so Contact Energy was split off from ECNZ, and its assets included all geothermal assets at the time. Contact was subsequently privatised and is listed on the stock exchange. The major shareholder is an Australian company, Origin Energy	Contact Energy is a publicly traded private generator/ retailer, with diverse generation assets including geothermal assets at Wairakei, Tauhara and Ohaaki (total geothermal generation = 300 MWe after allowing for station derating). It is currently partnering with Taheke 8C and Incorporated Blocks in the exploration of the Taheke geothermal field, which has involved the first Greenfield drilling since the 1980's. Contact is in the process of developing the first stage of the Te Mihi station as a partial replacement for the existing 52 year old Wairakei Power Station. It is investigating further development at Tauhara where it has consents for a 250 MWe development. Some staff have assisted Origin in EGS development assessments in Australia.

Company/Agency	Genesis	Activity and Notes
Mighty River Power	Following the split of Contact, ECNZ began to develop a business case for further geothermal investment. Further competition in the electricity market was required so ECNZ was split further into three additional State Owned Enterprises of which all geothermal interests went to Mighty River Power.	Mighty River Power is a SOE generator/ retailer, with diverse generation assets including geothermal assets developed in partnership with others or operated for others at Mokai (operator and later 25% shareholder), Rotokawa (partner/operator), and Kawerau (partner/operator) and further exploration at Ngatamariki (partner) (total generation under their operation = 394 MWe. Mighty River Power continues to look at domestic investment and is also investing internationally through GeoGlobal LLC in USA, Chile, and Germany.
Bay of Plenty Energy Ltd	Following the forced separation of an electricity supply authority, energy functions including the early binary cycle power plant developed at Kawerau were vested in Bay of Plenty Energy Ltd, which was purchased by a major private New Zealand energy investor (Todd Energy)	Bay of Plenty Energy maintains the operation of the Kawerau TG1 and TG2 power plants that take waste water from the Tasman Mill steam supply. BOPE has looked at potential new investments
Top Energy Ltd	Top Energy was a Northland electricity supply authority that had developed the Ngawha 1 plant originally. Under the electricity reforms it became a lines company but was able to retain the Ngawha plant through an exemption related to threshold size.	Top Energy is a consumer-owned trust with a focus on the distribution of electricity through a significant area of Northland. With relaxation of electricity reforms, and following long term testing of effects of the first stage 10 MWe development on local springs, it has been allowed to invest in the second stage 15 MWe development, and will consider further investment. The geothermal generation which they own and operate supplies a significant portion of the electricity requirements of their area.
Eastland Group	Eastland Group evolved from community asset interests primarily in the Gisborne region. It owns infrastructure assets such as an airport, shipping port, and electricity distribution lines. The recent electricity reform relaxation has enable the purchase of generation assets	Eastland Group (and Eastland Generation within that) is owned by the Eastland Community Trust on behalf of the Gisborne community. It has recently acquired the KA 24 geothermal power station at Kawerau, although the plant is not in the Gisborne area. Investment location was still partially constrained by governments separation rules related to lines companies and energy assets.
Crown Research Institutes (Government-owned research agencies)		
GNS Science	Formerly known as the Institute for Geological and Nuclear Science, the Wairakei office and laboratories in particular have a direct genesis in the original geothermal research work and staff of the old Department of Scientific and Industrial Research (DSIR)	GNS Science is a multi-discipline research institute that mixes leading edge research with commercial application. The team is active both domestically and internationally. International work includes contracted research and training. The GNS Science analytical laboratory is annually rated amongst the world's top geothermal laboratories for waters and gases.
Industrial Research Limited	This is a further spinoff of applied research personnel from the DSIR.	This includes a small team dedicated to development of code for geothermal reservoir simulation, funded largely through commercial applications for clients. A second group is researching high temperature cements to reduce the risk of casing collapse in geothermal wells.

Company/Agency	Genesis	Activity and Notes
Universities		
University of Auckland, University of Canterbury	These are long-established public universities. Since 1979, the Geothermal Institute has provided research and training for the New Zealand and international geothermal industries	New Zealand universities are centres of training and research, generally recovering costs from its students, through its projects and through government and other public-good science research funding. The University of Auckland has re-established the Geothermal Institute and continues to be a strong point of international linkage for training / research. It convenes the annual New Zealand Geothermal Workshop.
Consultancies (all consultancies are private)		
Parsons Brinckerhoff	GENZL was set up as a joint venture between New Zealand companies to develop geothermal fields internationally. It was bought out by staff and continued geothermal consulting work. ECNZ had a design arm known as DesignPower which undertook its own station design, and was part of a vehicle that ECNZ intended to take it into international markets including Philippines and Indonesian geothermal investments. Eventually DesignPower took over GENZL, then was sold to Parsons Brinckerhoff (PB) one of the largest engineering consultancies in the world. Note that PB had previously acquired Merz and McLellan but its current geothermal expertise is primarily based in New Zealand for all of its international work.	PB is a privately owned consultancy offering expert engineering consultancy services. To offer a complete service it has standing arrangements with GNS Science and the University of Auckland.
Sinclair Knight Merz	The New Zealand consultancy Kingston Morrison was chosen as a vehicle through which government scientists and engineers could be made available for work in the Philippines. Kingston Morrison eventually built up its own expertise. Through mergers it became Kingston Reynolds Thom and Allardice, then KRTA before being merged with the international projects firm called Sinclair Knight Merz (or SKM), headquartered in Australia.	SKM offers broad consultancy services and can fully service geothermal clients with in-house engineers (including power plant, steam field and drilling engineers) and scientists
Beca	In 1918, Beca was established in New Zealand with only three employees and is still headquartered here. Now, Beca has a substantial Asia Pacific footprint with over 2,500 employees operational in 17 offices across the world.	Beca is one of the largest employee-owned engineering and related consultancy services companies in the Asia-Pacific, with one market being the power sector. Beca has been the principal sub-consultant to Hawkins Construction for the construction of the Kawerau and Nga Awa Purua power stations. They offer architecture, structural and civil engineering, geotechnical and fire engineering design services.

Company/Agency	Genesis	Activity and Notes
Other Major Developers (also see Maori Trusts and Agencies)		
Norske Skog	Norske Skog is a major Scandinavian pulp and paper manufacturer, which acquired part of the Tasman mill at Kawerau. The Tasman Mill was the first large scale user of geothermal energy in New Zealand where supply commenced in 1957 prior to the commissioning of Wairakei. The Tasman Pulp and Paper Company was incorporated in 1952 initially as a joint venture between Fletcher Holdings, Reed International and the NZ Government. Eventually Fletchers took over the company. In 1979 all steamfield assets were transferred to the Ministry of Energy in return for a long term steam supply contract. Mill assets were subsequently purchased by Norske Skog.	Norske Skog is a privately owned international company, with their facilities at Kawerau being the second largest consumer of electricity in New Zealand, after an aluminium smelter. It is a significant regional employer so has drawn government interest in maintaining viability. The government was active in a recent deal which saw Crown assets transferred through Mighty River to Ngati Tuwharetoa Geothermal Assets, and long term energy arrangements made between Mighty River and Norske Skog. The Norske Skog plant receives 300t/h of steam which is used for heating and to a less extent electricity generation (8 MWe is installed). There are now plans to expand onsite generation by 20 MWe.
Service Companies		
MB Century	The original Ministry of Works (later Ministry of Works and Development) team at Wairakei was responsible for drilling, well measurements (and development of required tools for this), steamfield and well design, heavy engineering and some operations. These functions continued after corporatisation. The Wairakei business was sold to Century Resources and then this was acquired by Oman interests to become MB Century.	MBCentury still own and operate drill rigs, design wells, design and build steamfield equipment, undertake measurements and develop downhole tools to do this, undertake plant overhauls and manage and operate assets on behalf of others.
Tiger	Tiger Energy Services is a US based energy technology and subsurface data acquisition company. A team was established in Taupo in 2009 to undertake local advanced measurements and to manufacture logging vehicles for the domestic and international markets.	Tiger is a private company that specialises in the development and application of advanced measurement tools and techniques, including for geothermal applications.
Hawkins Infrastructure	Hawkins was established as a building company on the New Zealand stock exchange in 1952 and has continued to expand. At one time it was part of the McConnell Dowell Group, but was sold back to private hands in 1994. Hawkins is involved as a major civil works contractor	Hawkins continues as a private civil contractor and has been an active participant in a number of recent Mighty River and Contact geothermal power station projects.
Tenix	Robt Stone was founded in 1948 as a private New Zealand company and grew as a mechanical engineering company from then. It was acquired by Tenix in 2007	Tenix is one of New Zealand's largest and most experienced mechanical engineering companies specialising in fabrication, project management & site construction, mechanical design and plant maintenance. They produce and install pressure vessels, heat exchangers, tanks and pipe work, both domestically and for export.

Company/Agency	Genesis	Activity and Notes
Page & Macrae Engineering	Established in 1954, Page & Macrae continues to grow. It recently carried out the mechanical installation including piping for the Kawerau 100 MW Geothermal Power Station.	Page & Macrae is a private company now with 195 employees that offers a wide range of engineering products and services from design through to fabrication, construction and installation. They have experience in mechanical equipment relocation, piping, maintenance and installation in the geothermal industry.
Fitzroy Engineering	Established in the late 1950s Fitzroy Engineering has become one of New Zealand's largest heavy fabrication and multi-disciplined engineering companies and has the ability to successfully deliver complex engineering scopes	Fitzroy Engineering is a privately owned mature business with a claim to be New Zealand's largest multi disciplined engineering company with experience in a range of areas including power generation. It has fabricated steam separators, geothermal heat exchangers, and has undertaken mechanical installation of equipment and piping for the stage 2 Mokai development.
Allied Industrial Engineering	AIE was established in 1994 and has continued to develop.	Allied Industrial Engineering is a private heavy industrial engineering service company specialising in component manufacture, engineering, maintenance and re-engineering services for heavy industries, including geothermal power generation, Services include turbine repair and maintenance and the design and manufacture of heat exchangers and condensers.
ARANZ	Applied Research Associates New Zealand Ltd was formed in 1995 as a research organisation developing and commercialising innovative technologies.	ARANZ is the lead developer of a software package known as Leapfrog for enhanced data display and formation visualisation
Maori Trusts and Agencies		
Tuaropaki Trust	Various land blocks were amalgamated in 1952 and placed under the Tuaropaki Trust. There are 3,900 ha of land that largely overlie the Mokai geothermal field but have been developed for farming, and to a lesser extent forestry and glasshouse operations. The Trust took an early interest in independent development of the geothermal resources under their land.	Tuaropaki Trust set up the Tuaropaki Power Company which has developed the Mokai Power station, the largest merchant power station in New Zealand, using Mighty River Power as the field and station operator. The Trust has arrangements with a glasshouse and now with the Miraka dairy company for geothermal heat supplies, based on commercial contracts. Note that these heat supplies are not cascaded from the power station, but operated in parallel with the power station with dedicated steam supplies, but shared reinjection.
Tauhara North No 2 Trust	Trust lands were originally made up of smaller land parcels that, for many years were leased by the government-owned Landcorp for farming operations. Tauhara North No 2 Trust was established in 1993 as part of a process of regaining control of the land for Ngati Tahu tribal interests for growth purposes	Tauhara North No 2 Trust has a mission to hold and grow the assets, to increase tangible benefits to all shareholders, to manage the resources in a sustainable manner, to provide excellent communications; and to constantly strive for continuous improvements. The Trust has now been a joint venture partner with Mighty River Power for developments at Rotokawa and for the newly commencing Ngatamariki development.
Ngati Tuwharetoa Geothermal Assets	Ngati Tuwharetoa Geothermal Assets was established in April 2005 to receive and own geothermal assets associated with supply of steam to the Norske Skog Tasman mill, this being the largest industrial supply of geothermal heat for industrial purposes and with a steam flow equivalent to that required for a 40MWe power station. This was partly as a settlement of a Treaty of Waitangi claim.	NTGA own and manage geothermal assets at Kawerau. Mighty River Power is the asset operator on behalf of the Trust. The Trust has taken a proactive position that has seen expansion of supplies to the adjoining SCA mill and is now linked to further planned expansion of supply in the vicinity.

2.2 Further Market Background

New Zealand is now entering a new and exciting era of geothermal development. Stimulation for the current growth in geothermal development is due to several factors which include:

- Declining gas reserves in the large, low-priced Maui gas field and renegotiation of prices,
- Concerns around the future cost and supply of imported fossil fuels (as an alternative generation fuel), coupled with rising domestic prices for these fuels,
- Availability of premium geothermal resources that represent the best practical option of all available generation options,
- Expansion opportunities on existing operations that provide attractive economics in the current domestic market,
- Readiness of developers to invest in resources through established staff bases and experience, coupled with availability of skills,
- Climate change concerns linked to the Kyoto Protocol and national requirement to reduce greenhouse gas emissions, and
- Government reforms to reduce investment barriers.

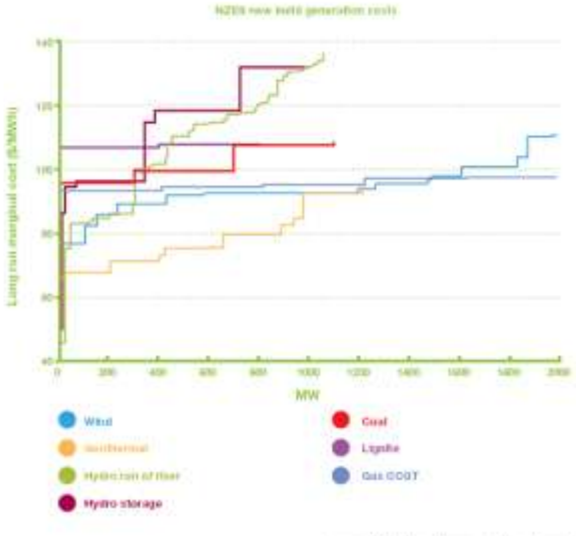
This has resulted in increased development for both electricity generation and direct heat using high temperature resources especially. It is interesting to note that enhanced geothermal systems (EGS) developments still do not feature in New Zealand developer or regulator thinking, largely because of the abundance of premium high temperature fields with further development potential, and the anticipated cost and complexity from developing EGS systems.

Future development will be led by a mix of private and public electricity generators (supplying heat and electricity), electricity lines companies, Maori Trusts (and other asset and land holding interests) and some major industries with heat and electricity needs. This will be focused on high temperature resources, but there will be ongoing investment at domestic level for direct use across the full range of resources.

New Zealand has an electricity generation system that is already dominated by renewable electricity sources. The system has a high proportion of hydro generation but with relatively little storage capacity making operation and prices sensitive to weather. Geothermal energy offers baseload energy independent of the weather, close to major load centres and at competitive development cost.

New Zealand electricity demand has been growing almost linearly for the last 30 years by about 660 GWh/year (before transmission and distribution losses of about 7.5%). It has flattened in the last 5 years and this may have a temporary suppressing effect on the domestic market generation build.

Figure 1 is taken from the Energy Strategy and shows quantities and long run costs (NZ$) associated with various energy sources. The striking thing about this graph, for which inputs were developed in consultation with industry, is that there are significant quantities of low cost geothermal and wind generation that should reasonably compete with fossil-fuelled generation options. Hence wind and geothermal generation are expected to dominate new capacity. The most competitive fossil-fuelled option is gas-fired combined cycle plant with gas at NZ$9/GJ and with CO_2 valued at NZ$25/t of CO_2. In a national context, the quantities of renewable energy options available are sufficient to satisfy 20 or so years of demand growth, unless electric vehicles develop at an unprecedented rate.



Source: Ministry of Economic Development

Figure 1: Long run costs for a range of generation options (from the *New Zealand Energy Strategy*)

All generation is bid into the wholesale market. In any half hour period all offerers of generation receive the price offered by the final plant required to match supply to demand. The most active trading is undertaken by the hydro and thermal stations, while wind and geothermal electricity (and a varying portion of thermal generation) is offered into the market at a zero or near zero price.

The following table shows the costs faced by various consumers linked to the National Grid and is taken from the Ministry of Economic Development's "New Zealand Energy Data File". Some companies are paying a relatively low price based on longstanding hedge arrangements, but eventually all prices will move to reflect current energy prices.

Table 2: Electricity market snapshot – 2010 March Year (taken from MED's *Energy Data File)*

Table G.6a: Electricity Market Snapshot - 2010 March Year

	ANZSIC 2006	ANZSIC 1996	Sales[1] MWh	Energy Cost[2] $(000)	Line Cost[2] $(000)	Total Cost[2] $(000)	Average Cost c/kWh	Number of Observed Connections[3]	Average Consumption MWh
Agriculture/Forestry/Fishing			**1,854,720**	**213,598**	**113,471**	**327,070**	**17.63**	**68,517**	**27.07**
Agriculture and primary sector support services	A01,A05	A01-A02	1,644,402	199,605	107,909	307,514	18.70	67,678	24.30
Forestry and logging	A03	A03	69,565	4,310	2,539	6,849	9.85	425	163.83
Aquaculture, fishing, hunting and trapping	A02,A04	A04	140,754	9,683	3,023	12,706	9.03	414	339.79
Industrial			**14,004,842**	**1,007,536**	**272,684**	**1,280,219**	**9.14**	**38,802**	**360.93**
Coal mining	B06	B11	78,951	6,822	2,770	9,592	12.15	62	1,278.64
Oil and gas extraction	B07	B12	29,140	2,213	1,916	4,130	14.17	138	210.50
Other mining and quarrying, and services to mining	B08-B10	B13-B15	401,826	27,088	11,698	38,786	9.65	540	743.58
Meat and meat products	C111-C112	C211	706,875	57,881	19,812	77,692	10.99	463	1,526.54
Dairy products	C113	C212	836,286	69,830	19,162	88,992	10.64	487	1,717.65
Other food products, beverages and tobaccos	C114-C12	C213-C219	636,765	55,331	22,753	78,085	12.26	2,061	308.99
Textile, leather, clothing and footwear	C13	C22	118,744	11,574	5,483	17,057	14.36	1,218	97.47
Log sawmilling and timber dressing, and other wood prod	C14	C231-C232	1,359,543	91,826	20,159	111,985	8.24	1,193	1,139.87
Pulp, paper and converted paper products	C15	C233	1,801,157	114,218	17,046	131,265	7.29	244	7,392.61
Printing	C16	C24	146,322	14,505	5,208	19,713	13.47	1,143	127.99
Petroleum and coal product manufacturing	C17	C251-C252	293,894	18,976	6,112	25,088	8.54	152	1,934.81
Basic chemicals and chemical products	C18	C253-C254	130,785	11,353	5,094	16,447	12.58	537	243.66
Polymer and rubber products	C19	C255-C256	243,247	22,682	8,464	31,146	12.80	526	462.69
Non-metallic mineral products	C20	C26	221,363	19,989	6,859	26,848	12.13	761	290.85
Basic ferrous metals	C211	C271	1,270,941	90,338	12,599	102,937	8.10	424	2,996.53
Basic non-ferrous metals	C213	C272	4,602,824	270,296	43,412	313,707	6.82	72	63,583.62
Basic non-ferrous metal products	C214	C273	6,064	646	314	961	15.85	64	95.04
Basic ferrous and other metal products	C212,C22	C274-C276	102,113	11,139	6,015	17,155	16.80	1,475	69.21
Transport equipment	C23	C281-C282	34,418	4,313	2,394	6,707	19.49	1,148	29.98
Machinery and Equipment Manufacturing	C24	C283-C286	161,684	17,122	7,101	24,223	14.98	2,747	58.85
Furniture and other manufacturing	C25	C29	262,996	25,803	12,793	38,596	14.68	2,821	93.23
Electricity supply	D26	D361	110,058	13,052	7,272	20,324	18.47	2,624	41.94
Gas supply (including LPG and CNG)	D27	D362	4,050	485	268	753	18.60	397	10.21
Water supply, sewerage and drainage services	D28	D37	254,908	27,047	14,640	41,688	16.35	7,722	33.01
Construction	E	E	189,888	23,005	13,337	36,342	19.14	9,782	19.41
Commercial *(including Transport)*			**9,166,108**	**926,901**	**452,630**	**1,379,530**	**15.05**	**164,811**	**55.62**
Wholesale and retail trade	F-G	F-G	2,341,321	252,086	110,374	362,460	15.48	42,601	54.96
Accommodation and food services	H	H	1,046,618	119,005	53,975	172,980	16.53	15,082	69.40
Road freight	I461	I611	57,114	6,257	2,632	8,889	15.56	1,054	54.16
Road passenger	I462	I612	22,741	2,643	945	3,588	15.78	365	62.37
Rail	I47	I62	78,785	6,429	5,212	11,641	14.78	880	89.51
Water	I48	I63	6,915	736	435	1,171	16.93	137	50.48
Air and space transport	I49	I64	97,638	7,318	4,424	11,742	12.03	559	174.67
Other transport and transport support services	I50, I52	I65-I66	221,424	21,253	10,592	31,845	14.38	3,307	66.96
Warehousing and storage services	I53	I67	158,123	15,542	7,306	22,848	14.45	3,860	40.97
Information media, telecommunications and postal servic	J, I51	J	494,771	36,386	21,492	57,878	11.70	9,554	51.79
Financial, property, hiring, professional and administrative	K-N	K-L	1,737,556	168,665	83,283	251,948	14.50	30,260	57.42
Public administration and safety	O	M	808,742	76,149	47,340	123,489	15.27	11,205	72.18
Education and training	P	N	686,371	71,826	34,751	106,576	15.53	8,679	79.08
Health care and social assistance	Q	O	715,526	66,493	28,406	94,899	13.26	9,038	79.17
Arts, recreational and other services	R-S	P-Q	692,462	76,112	41,464	117,576	16.98	28,232	24.53
Residential			**13,400,215**	**1,938,124**	**958,732**	**2,896,856**	**21.62**	**1,653,781**	**8.10**
Total Sales			**38,425,884**	**4,086,159**	**1,797,516**	**5,883,675**	**15.31**	**1,925,911**	**19.95**

Notes to Table G.6a:

1) Excludes on-site cogeneration.
2) Some financial information has been estimated based on the average March year cost for the relevant industry (by ANZSIC classification) or other information where appropriate. Additionally, financial information provided here contains error for reasons outlined in the Preface. While absolute values for these factors are at least indicative, caution should be applied when comparing the informationin this table to table G.5a and previous editions of the EDF
3) Connections are defined by Installation Control Points (ICPs) and in all instances are used to represent sectorial customer numbers. From this, average consumption and electricity prices are calculated.

3. *The Resource Management Act as a Means of Project Permitting and an Alternative to Resource Leasing*

While New Zealand has a leasing system for oil and gas prospects, the allocation of geothermal resources is done via a process that provides consent for use of the resource, for a defined volume and defined period. The legislation is New Zealand's Resource Management Act 1991[1]. While oil and gas allocation is managed by central government, geothermal resource management has devolved decision making on resource and development approvals. These occur at regional and district government. There is no bidding system for resource development. Rather, any person can seek consents to develop any resource. An application is considered in the light of the sustainable management context of the Resource Management Act, with more detail on how this is interpreted at regional level through regional policy statements and regional plans, wider government imperatives, and the response of the public to proposed development.

There are positives and negatives to such a permitting scheme, however, 289 MW of geothermal electricity capacity was developed in the US between 2000 and 2009, with a similar capacity being developed in New Zealand over a similar period despite a weaker economy and smaller resource base. There may be some lessons to be learned from alternative permitting systems.

The current system of geothermal management under the RMA requires a developer to negotiate formal contracts with all land owners where access is required; defining what rights each party have in respect to accessing the geothermal resource. This process does not provide certainty of access which can be a deterrent to investors, particularly from overseas. There is no formal process of arbitration and no legislative guarantee that the explorer will be given the first right to extract the resource. In contrast, for oil and gas (covered by the Crown Minerals permitting regime), arbitration is an option for land access negotiations, although arbitration has never been required to date. It has been argued that geothermal explorers do not have enough certainty to explore because someone else can come in and apply for resource consent after the explorer has invested in exploration in a particular area. However, it is not clear that the lack of a legislative guarantee over the right to develop is necessarily of concern and this potential problem has not arisen so far. An application for resource consent to develop a resource requires the provision of considerable information. Hence, the ability of a new party to gazump an existing explorer to develop for the same use may not be as easy as some assume or suggest. There is potential that such a situation could delay or even terminate the development of a resource, or that there could be conflict between those seeking to use the same resource for different types of development. Geothermal system management under the RMA takes account of the capacity of the resource for extractive use. Problems of resource over-use that have occurred in other jurisdictions are much less likely to occur under the RMA regime.

---

[1] For an everyday guide to this Act see http://www.mfe.govt.nz/publications/rma/everyday/ while for the full Act with amendments see http://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

4. A Summary of the Status of Ongoing and Advanced Geothermal Activities

For expanded details of projects refer to Appendix 2.

4.1 Electricity Generation Projects

Electricity generation projects are located in the Taupo Volcanic Zone (TVZ) and at Ngawha in Northland, where New Zealand's high temperature hydrothermal resources are located. Some of these fields have encountered temperatures exceeding 330°C at depths of less than 3 km.

The heat source beneath the TVZ is believed to be an upwelling mantel plume coming up behind the subducting Pacific plate. Magma at a depth of around 10 km vents heat to the surface through a combination of conduction aided by convection. All development attention has been focused on the convective cells because these are premium low cost resources, but it is possible that there will be some very attractive EGS candidate sites at the margins of the TVZ or within sectors of developed sites, including sites at Whakatane, Horohoro and Mangakino.

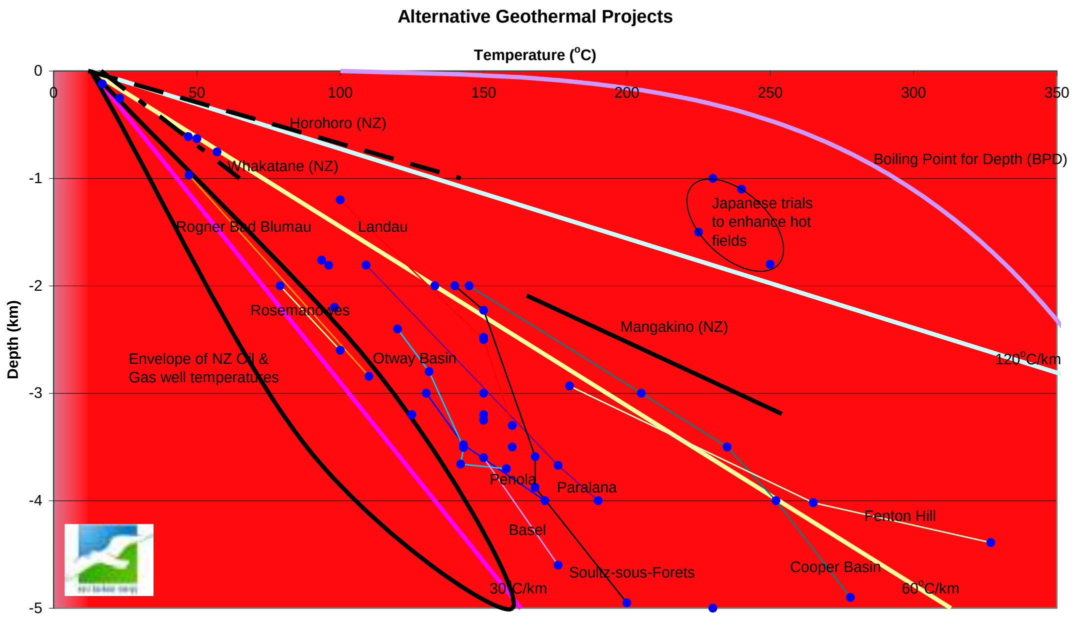


Figure 2: Comparison of Whakatane, Horohoro and Mangakino field temperature gradients with some EGS and HSA developments internationally.

The following figure shows the buildup of geothermal generation capacity in New Zealand, with geothermal energy currently supplying 12 – 13% of all electricity demand, depending on demand conditions. A projection based on planned developments is also shown.

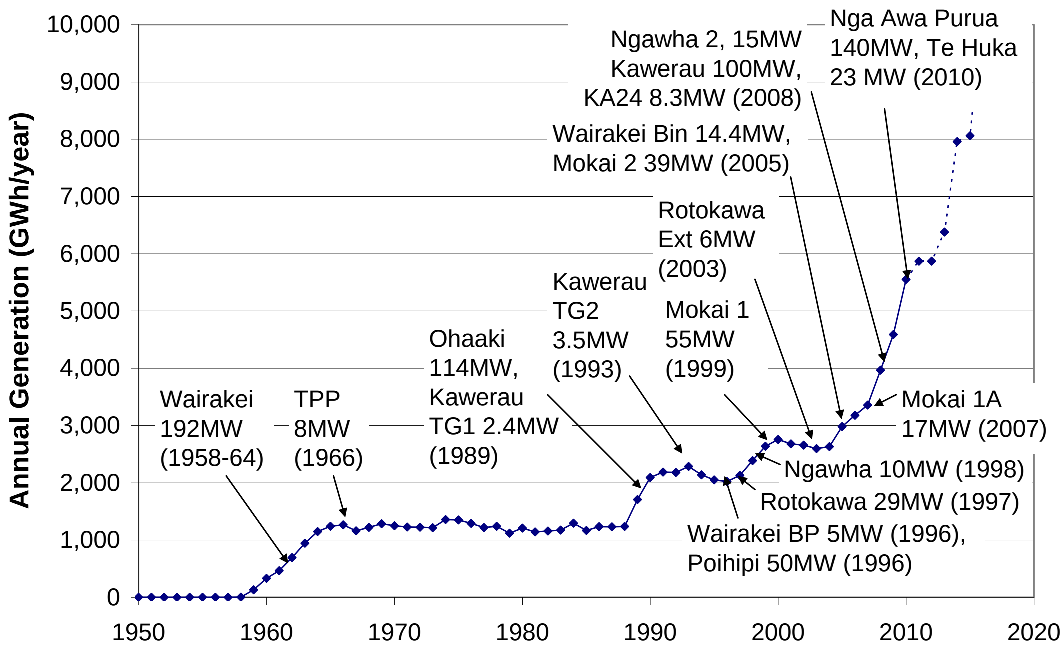


Figure 3: Buildup of geothermal generation in New Zealand

The following figure shows a concentration of projects in the vicinity of the original Wairakei development (red ovals roughly encompass the steamfield pipe networks).

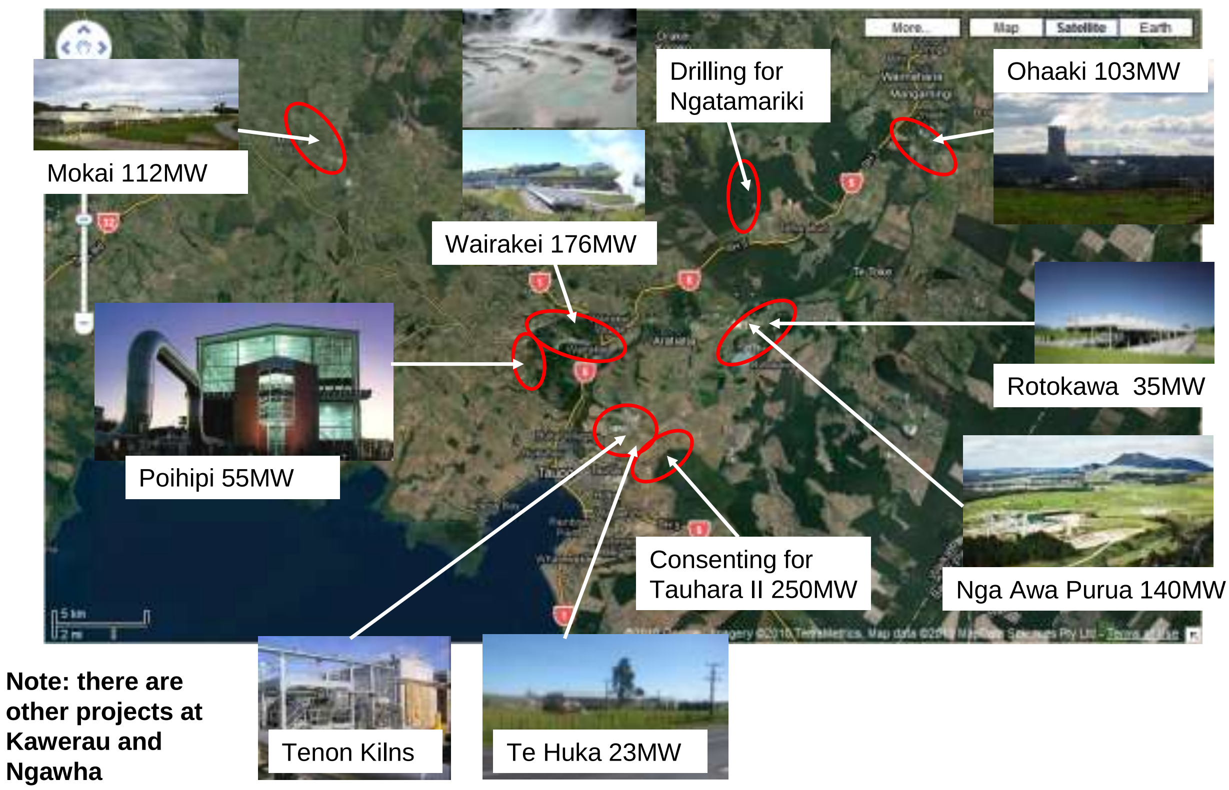


Figure 4: Montage of developments in the vicinity of the original Wairakei development.

The following table is based on the form used in the World Geothermal Congress Country Updates. Brief comments on only some plants follow:

- Wairakei power station continues reliable operation over 50 years after initial commissioning, but has required considerable adaptation in the field and within the station. A development called Te Mihi is intended as a partial replacement of the original station, and construction has commenced. The initial Te Mihi development will be located nearer to the principal upflow in the Wairakei field, will be a 166MWe plant that will replace 45 MWe of existing Wairakei plant and is due to be commissioned in 2013. Contact Energy is the asset owner.
- Kawerau continues to be a focus for ongoing development for both electricity and large-scale industrial heat supply. This is assisted by progressive developers and operators including Ngati Tuwharetoa Geothermal Assets, Norske Skog Tasman and Mighty River Power.
- The Ohaaki power station operates below capacity due to production limitations. Contact Energy is the asset owner.
- The Rotokawa field is a large field with the possibility of further expansion. The most recent development is the 140MW Nga Awa Purua station, that features a triple flash design in the field and includes the largest single shaft geothermal turbine in the world. Mighty River is a joint venture partner with Tauhara North No 2 Trust and is the operator.
- The Ngawha field has been subject to staged development, and already meets a substantial portion of the regional electricity requirements. Top Energy (predominantly a lines company) owns above-ground assets and is the operator.
- The Mokai development includes the largest merchant power station in New Zealand, and was developed primarily by a Maori Trust through the Tuaropaki Power Company. This company is also involved with industrial-scale heat projects. Mighty River is the operator (and now part-owner of TPC).
- Tauhara consents have been approved, and the station could potentially be the largest geothermal station in New Zealand depending on staging. Contact Energy will be the developer.
- Ngatamariki consents and contracts are in place with site works about to start. This is being developed by the same joint venture that implemented the 140MWe Nga Awa Purua development: Mighty River Power with Tauhara North No 2 Trust.
- Rotoma and Tikitere are each being developed by independent Maori trusts working with a manufacturer (Ormat).
- The Taheke development is a joint venture between Taheke 8C and Adjoining Blocks Incorporation and Contact Energy. It has already involved 3 deep exploration wells, these being the first greenfield wells drilled since the end of the Crown drilling program in the 1980s.

Table 3: Utilisation of geothermal energy for electric power generation

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (please specify)
D = Dry Steam

3) Totals exclude retired plant

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1]	Type of Unit[2]	Total Installed Capacity MWe	Annual Energy Produced GWh/yr	Total under Constr. or Planned MWe
Wairakei	Wairakei	1958-63	4	R	4 HP - BP	36		
			9	Op	2 IP - BP	157	1249	
					4 LP - C			
					3 MP - C			
		1996	1		1 LP - BP	5		
	Wairakei Binary	2005	3		B	14.4	118	
	Poihipi	1996	1		D	55	362	
	Te Mihi (replacement for Wairakei)							240
	Geotherm							55
Kawerau	Tasman BP	1966	1	R	1 BP	10		
	Tasman BP	2004	1	Op	1 BP	8	43	
	TG1	1989	2		B	2.4	8	
	TG2	1993	1		B	3.5	26	
	KA24	2008	1		B	8.3	65	
	Kawerau	2008	1		2F	100	877	
	NST				B			20
	KA22				B			12
Reporoa	Ohaaki	1989	2	R	1 HP - BP (ex-Wairakei)	11		
				Op	1 HP - BP (ex-Wairakei)	11	410	
		1989	2	Op	1F	92		
Rotokawa	Rotokawa	1997	4		H (1F, B)	29	273	
	Rotokawa Extension	2003	1		B	6		
	Nga Awa Purua	2010	1		3 F	140	1165	
Northland	Ngawha	1998	2		B	10	200	
	Ngawha 2	2008	1		B	15		
Mokai	Mokai 1	1999	6		H (1F, B)	55	927	
	Mokai 2	2005	5		H (1F, B)	39		
	Mokai 1A	2007	1		B	17		
Tauhara	Te Huka	2010			B	24	191	
	Tauhara							240
Ngatamariki	Ngatamariki							82
Rotoma	Rotoma							35
Tikitere	Tikitere							40
Taheke	Taheke							?
Total[3]			43			792	5,914	724

4.2 Heat Projects

The New Zealand view on heat projects is evolving. There has been steady growth of geothermal heat projects since the 1950s but much of this is associated with large-scale industrial projects and much of the growth since the 1980s has been in this category. These have almost all been on high temperature fields that do not lend themselves to cascade use, so have been independent or parallel[2] developments to any electricity developments.

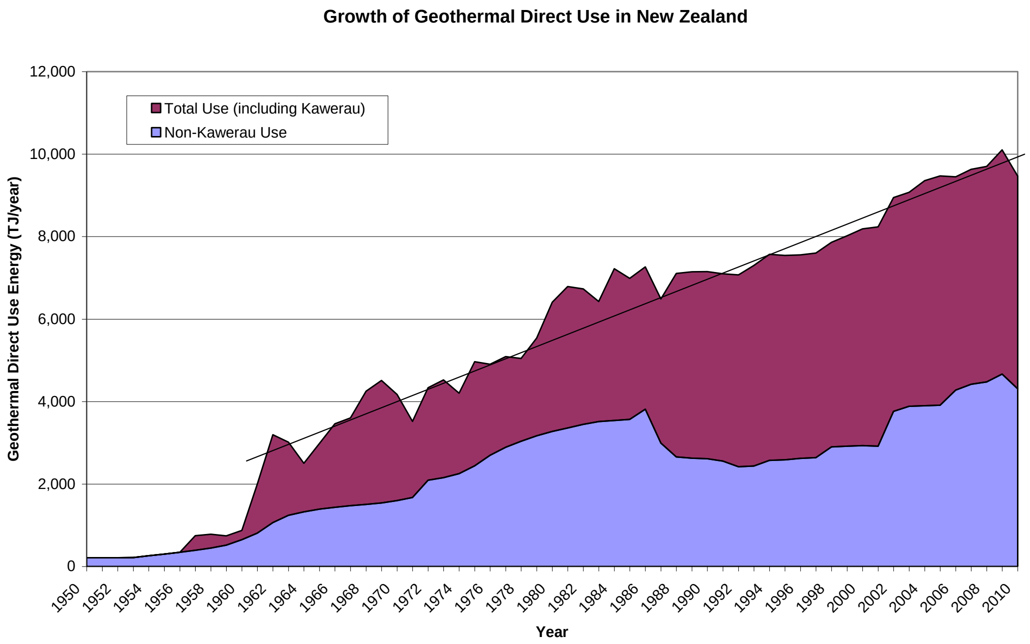


Figure 5: Historical growth in New Zealand geothermal direct use.

For many years heat projects were considered as options to soften public opinion towards geothermal development. However, studies have shown that where developments are of sufficient scale or if they share facilities with geothermal power stations, then commercially satisfactory arrangements can be made for all parties. Recent developments have been undertaken on this commercial basis. One of the challenges is to overcome the market failure associated with lack of knowledge of the option.

The following table gives a sense of scale of some of the major direct use projects in New Zealand.

[2] "Parallel" developments contrast with "cascade" or "series" developments in that the heat project is receiving the same premium heat that would be supplied to a station, rather than some waste stream.

Table 4: Summary of major direct use projects in New Zealand including estimated demand for projects commissioned in 2011.

Plant	**Energy Use (TJ/Year)**	**Cumulative Energy Use (TJ/year)**	**Comments**
Kawerau industrial supplies	5,224	5,224	Industrial
NETCOR tourism facility	820	6,044	Commercial tourism (not industrial), receives flashed brine only
Ohaaki kilns	438	6,482	Industrial, receives flashed brine from Ohaaki power station for cascade use
Tenon kilns	431	6,913	Industrial
SCA mill, Kawerau	300	7,213	Industrial – commissioned 2010
Mokai glasshouse	300	7,513	Commercial (not industrial)
Waikite pool	275	7,788	Swimming pool complex, and receiving fluid from a spring so not associated with anything other than natural emissions – most heat rejected to atmosphere
Miraka milk drying plant	270	8,058	Industrial – commissioning in progress
Wairakei prawn farm	270	8,328	Commercial (not industrial), receives flashed brine only
Geotherm glasshouses	27	8,355	Commercial (not industrial)
Hanmer Springs	15	8,370	Swimming pool and spa complex
Many others	<15 each	10,122	

5. *Policy Initiatives for the Encouragement of Renewables Generally and Geothermal Energy Specifically*

New Zealand Governments have a strong aversion to subsidy and trade barriers and only looked at interventions where there was some evidence for a market failure or where there are natural monopolies.

Any discussion of Government initiatives to encourage renewables (and therefore geothermal) development is complicated by a change of Government at the end of 2008. The new National Party-led coalition Government has reviewed a number of past initiatives and put greater emphasis on economic growth, especially in the face of global recession, and security of supply.

5.1 A New Zealand Energy Strategy

The "*New Zealand Energy Strategy and the New Zealand Energy Efficiency and Conservation Strategy*" (NZES and NZEECS) has been made available for public comment and will shortly be released in final form by the Government. This document and other linked infrastructure documents set out a coordinated energy strategy. Among initiatives, a target has been repeated from a previous NZES for 90% of electricity generation to be from renewable by 2025 (74% was achieved in 2010). The Energy Strategy recognises the potential benefits from low temperature resources and from our deep geothermal resources.

5.2 Resource Allocation Procedures

Resource allocation and the management of effects of development in New Zealand are handled through the Resource Management Act 1991 by local Government or the Environment Court. Over the last five years efforts have been made to improve the quality of decisions and associated processes, as well as reduce the time required to obtain consents. The Government is taking further steps to improve the process.

Within the planning environment there is provision for what is termed a National Policy Statement (NPS) established by Government to direct the local councils in deciding on consent applications. In this context an NPS on Electricity Transmission was developed in 2008. This gives clear direction to the Regional Councils under the Resource Management Act requiring these decision makers to consider the national significance of a reliable and secure electricity supply when assessing transmission proposals. Transmission constraints can impact on the rate of generation development.

Similarly, an NPS for Renewable Electricity Generation was developed to direct councils to take account of the national significance of renewable electricity generation when considering consent applications, and was gazetted in April 2011.

At the project level, central government has made submissions in support of consent applications by developers to local authorities when renewable energy projects start the resource allocation process.

5.3 Local Authority Initiatives

At local government level, Waikato Regional Council's (WRC's) Regional Policy Statement and its Regional Plan with respect to geothermal development has been revised. These are key regional planning documents under the Resource Management Act. About 80% of New Zealand's high temperature geothermal resources are thought to lie in WRC's region. These documents enable developers to identify resources that can be readily developed and target their attention accordingly. The Bay of Plenty Regional Council (which is responsible for almost all of the other high temperature resources, and which currently has 66% of direct use by energy in its area) is now revising its planning documents and has partly modelled these on WRC's documents.

A longer-standing initiative by Regional Councils is the establishment of Peer Review Panels to review the performance of developers on each field to help ensure sustainable development. These panels of experts have an ongoing review function throughout the operational life of a project.

5.4 Bringing a Cost of Carbon to the Market

Any value placed on carbon emission will have the effect of encouraging low emissions technologies such as geothermal energy (for heat or electricity generation).

The Government recognized Kyoto Protocol obligations through the Climate Change Response Act 2002. As an interim measure this Act introduced a scheme known as Projects to Reduce Emissions in which carbon credits could be tendered for. There have been several geothermal projects, including the Kawerau KA 24 development that benefitted from this, though the scheme was subsequently effectively scrapped.

In 2008 Parliament passed the Climate Change (Emissions Trading) Response Bill, which amended the earlier Act to establish an emissions trading scheme (ETS). While there has been some modification to the original concept, New Zealand now has an operational emissions trading scheme.

5.5 Initiatives to Enable Investment

Some of the smaller geothermal electricity generation stations could be classed as distributed generation. In 2007 regulations were introduced around the connection of distributed generation to facilitate its uptake, where connection is of appropriate standards.

Like many countries, New Zealand had previously legislated splits in the electricity industry between monopoly elements (lines functions) and market elements such as electricity generation and retail, through the Electricity Industry Reform Act 1998. This effectively removed some potential geothermal investors from the market. The Electricity Industry Act 2010 relaxed a number of aspects in terms of:

- Allowing lines companies to more easily sell the output of generation they were permitted to own;
- Allowing lines companies to be involved in generation and retailing without limits outside their lines area, and
- Amending the definition of renewables to include geothermal and hydro (previously excluded), to allow the lines companies to freely invest in this type of renewable development.

One specific initiative to encourage geothermal investment relates to Crown wells. The Crown owned around 100 geothermal wells drilled in the 1960s, 70s and 80s under previous government exploration policies. These assets were managed by the

Treasury in a caretaking role, but the existing exploration wells and the information associated with these could give potential developers greater confidence than would normally be possible with a greenfield development. Some of these wells and related assets at Kawerau have now been transferred to developers through the state-owned Mighty River Power, in what could be a model for other fields.

5.6 Treaty Settlements and the Role of Indigenous People in Future Development

A central document in the establishment of New Zealand as a nation was the Treaty of Waitangi signed in 1840 between the British Crown and representatives of many of the indigenous Maori tribes. In recent decades the Government has addressed restitution for past actions which were not in the spirit of this Treaty through Treaty Settlements and the Waitangi Tribunal. A number of settlements have recently been reached that relate to tribes with geothermal interests. The outworking of these settlements has already seen former government-owned steamfield assets at Kawerau pass to one company representing Maori interests (Ngati Tuwharetoa Geothermal Assets).

Note that the Government sees the potential for some of the existing Crown-drilled geothermal wells to form part of future Treaty settlements.

Maori-owned land is often held on a collective basis by internally managed Trusts. The various Trusts have diverse interests but, where they own land over geothermal resources, frequently have a strong interest in geothermal development whether for tourism, heat supply, electricity generation or thermophilic organisms. They already have a kaitiakitanga (or guardianship) role.

5.7 Government-Funded Research and Development

Prior to the depletion of the Maui gas field, New Zealand Government funding for geothermal research was in decline. The anticipated depletion of Maui plus the recognition of the role of geothermal as a renewable, indigenous, low carbon source for electricity generation and heat led to an increase in funding since 2006. These funds are applied to research in conventional systems, low temperature resources and deep geothermal exploration

The Ministry of Science and Innovation (MSI) is New Zealand's largest government funder of research and development. Geothermal technologies are supported by MSI through the Science Strategy and Innovation group (which funds research organisations) and through Business Innovation and Investment group (which funds firms directly). The New Zealand Government also supports a 5 year research programme into geothermal-related technologies through the Royal Society of New Zealand.

5.7.1 Science Strategy and Innovation

$6.50M p.a. is invested in geothermal research contracts supporting targeted basic and applied research.

Of this amount, $3.275 M p.a. (or $15.6M total investment) has been mapped to core funding for GNS as a Crown Research Institute. GNS has responsibility for the direction and performance of this funding, in line with its core purpose which includes undertaking research that drives innovation and economic growth in New Zealand's geologically-based energy and minerals industries.

Further funding of $1.46M p.a. is contestable, and is currently held in two research contracts:

- Contract UOAX0713 titled Deep Geothermal Resources (total investment $4M over 6 years) led by the University of Auckland, and
- Contract C08X0902 titled Cements for Extreme Environments (total investment $3.25M over 4 years) led by Industrial Research Ltd.

There is a further programme of $1.77M p.a. being a 5 year research programme funded by the Royal Society of New Zealand titled:

- The Underground Eye (total investment of $8.84M over 5 years) led by the University of Auckland.

5.7.2 Business Innovation and Investment

A small amount of funding for geothermal technologies is invested directly with companies according to demand, with the amount varying each year. This funding is for projects (providing 1:1 support for firms to undertake innovative projects to develop new products) and for capability building (supporting firms to employ undergraduate and masters students to undertake internships, engage experts to assess their R&D strategy and provide advice).

6. A Brief Review of R&D and of Specific Projects in New Zealand Underway and Planned

6.1 Overview

Geothermal research in New Zealand seeks environmentally sustainable growth in New Zealand's geothermal electricity generation, including utilisation of deep geothermal resources; an increase in direct use applications; and development of new industries and applications leveraged from geothermal resources. Research is collaborative, multidisciplinary and closely aligned with industry needs. Key research providers are GNS Science, the University of Auckland and Industrial Research Limited. The University of Canterbury has recently been developing geothermal research streams.

A drive towards renewable and environmentally sustainable electricity generation since 2000 has seen the geothermal industry in New Zealand expand rapidly, and government research funding has grown to match that expansion (ca. $5m pa). In addition, the geothermal industry (mainly Contact Energy and Mighty River Power) directly funds ca. $1m in research projects annually, with an additional ca. $2m of in-kind cofunding; including access to data and geothermal sites, drill core, and funding for geophysical surveys. This cofunding is essential for the undertaking of effective geothermal research.

6.2 IPGT Interest Aspects

Those R&D projects that are directly relevant to the IPGT technical streams have been summarised below (and are detailed in Appendix 3).

<u>High temperature tools</u>. Utilisation of hot, deep geothermal resources is requiring assessment of rock, fluid and reservoir behaviour. High temperature wireline logging and borehole imaging tools are being tested and used in New Zealand and interpretation methodologies, particularly around acoustic borehole imaging, are being advanced. High temperature tools are not currently being developed in New Zealand, however there are plans being worked on to collaborate in the global development of high temperature tools, such as mircoresistivity sensors, full wave sonic tools and borehole seismographs. It is anticipated that testing could usefully be pursued at New Zealand geothermal sites once these tools are in prototype form.

<u>Lower cost drilling</u>. New Zealand geothermal operators are active in considering and utilising methods and approaches to reducing drilling costs while commensurately maintaining the quality of drilling operations. In terms of developing new equipment and techniques, there are no active New Zealand research workstreams underway seeking to lower cost drilling. This is a workstream that could develop further with geothermal operator involvement in this IPGT task.

<u>Induced seismicity</u>. New Zealand's induced seismicity research is closely aligned with international interests in the US, Europe and Australia.

Research streams include

(i) improved methods for locating micro-earthquakes, using surface and down-hole seismic networks,
(ii) characterising induced seismicity to better understand inducing mechanisms and stress triggers, and

(iii) development of risk management strategies to mitigate against large seismic events.

Expansion in this area is anticipated across all existing themes, with the addition of a new future project seeking to monitor the long-term behaviour of EGS geothermal systems.

Stimulation procedures. The New Zealand geothermal industry has some operational procedures that are used for stimulation. While no practical field tests are actively being undertaken in an R&D sense on projects to enhance permeability in deep geothermal systems, some flow-in-fractured-media modelling is being done to better understand the factors controlling successful stimulation programs.

An important related project is the development of a high temperature physical-and-mechanical rock analysis capability, especially for high temperature geothermal environments. This is a work stream that is currently being developed. There are potential linkages to be explored including with the New Zealand hydrocarbons industry, as well as overseas collaborations.

Exploration technologies. An amount of New Zealand's geothermal research is focussed on delineating and characterising geothermal resources for exploration, development and production.

Three main themes are apparent in exploration technologies:

(i) Fracture characterisation: rheological and hydrothermal alteration studies, rock property testing and borehole imaging, and fracture & fluid flow modelling to better understand the role of fractures in focusing hydrothermal fluid;

(ii) Deep resource delineation: combined geophysical methods (MT, seismic, gravity and magnetics) to identify heat sources, permeability, fluid flow and drilling targets.

(iii) Fluid-rock interaction: assessing changes in rock porosity, fracture permeability, well productivity and infrastructure resulting from fluid-rock interactions at high pressures and temperatures; as well as understanding of deep stratigraphy and structure.

Modelling. R&D effort is being pursued in model development with geothermal modelling projects seeking to provide more efficient and effective decision making; from the exploration of a new field, to reservoir development and production, assisting with future development strategies. Projects include the development of improved TOUGH2 reservoir models for Taupo Volcanic Zone (TVZ) geothermal fields that incorporate data from chemistry, geology, geophysics and reservoir engineering. Development of TVZ models that incorporate brittle ductile rheology are also being pursued. A new 3D geological modelling and visualisation software (Leapfrog Geothermal) is combining key components of a field, including stratigraphy and structures, rock properties and reservoir parameters.

In a similar, parallel development, a well established finite element flow-through-rock code (USGS Sutra) and well log data are being used to characterize why geothermal development is high risk. Efforts to illustrate these results in software (Geomodeller) and on a 3-D projection screen are also underway.

6.3 Other Research Aspects

New Zealand is involved with extensive research outside of the core areas of interest on the part of IPGT. Among these other areas:

High Temperature Cements. Geothermal drilling is occurring in more challenging environments. Expertise in cement chemistry and geothermal environments is being brought together to develop new cement systems that will perform effectively in high pressure, high temperature and chemically corrosive geothermal conditions.

Above Ground Technology Development. The New Zealand Heavy Engineering Research Association (HERA) is conducting a research program on "Low enthalpy heat to electrical energy conversion". This program aims at establishing above ground technology for the processing of lower heat geothermal resources into electrical energy for local and export markets. The program is performed in co-operation with two major NZ heavy engineering fabricators and the Mechanical Engineering Department of the University of Canterbury and receives 50% co-funding via the MSI TechNZ funding pool.

Low Enthalpy Geothermal. A challenge in the New Zealand market is to overcome information barriers to the increased uptake of ground sourced and geothermal energy. Work involves technology evaluation, development of technology best practise guidelines, social science and Maori research, resource quantification, development of geophysical techniques and development of material suitable for introduction into the NZ planning framework.

7. *Geothermal Education Support and Initiatives*

New Zealand has a long history of geothermal research and teaching. In 2010 there were 45 students enrolled in Master and PhD programs carrying out geothermal related research at the University of Auckland, Victoria University Wellington, University of Canterbury, Massey University, and Waikato University. In particular, there are large research groups at Auckland (geothermal reservoir simulation, geothermal engineering, geothermal geophysics, and structural and geothermal geology), and Canterbury (geothermal power plant engineering and production chemistry, volcanology, and geothermal fluid chemistry); Canterbury also offers an undergraduate geoscience paper 'Water and geothermal systems'.

The main centre for geothermal training in New Zealand is the Geothermal Institute at the University of Auckland. Between 1979 and 2002 the Geothermal Institute hosted approximately 1300 students attending academic and industry training courses at the Geothermal Institute. That period saw the production of 880 student reports and theses, 100 conference papers, 150 refereed papers, and 70 technical reports. Direct funding for the Geothermal Institute was discontinued in 2002 as NZ Government re-directed funding to primary education in developing nations.

However 2007 saw the start of the one semester Post Graduate Certificate in Geothermal Energy Technology (PGCert Geothermal) at the University of Auckland. Enrolments have been predominantly international, although New Zealanders also participate (~20% of graduates up to 2010). The PGCert Geothermal is now in its fifth year; with 73 participants in five years (21 students in 2011).

This year (2011) has seen the formal re-establishment of the Geothermal Institute at the University of Auckland and also the first intake of students for Master of Energy programme, which includes an option for a geothermal specialization. There are currently twelve students who have chosen a geothermal component for the Master of Energy degree. Both of these initiatives are being supported with scholarships funded by the New Zealand Government. In 2011 it has provided full scholarship support for eight Indonesian students taking the PGCert Geothermal. The number of scholarships will be increased in 2012 up to 25 and they will be available for the PGCert Geothermal, the Master of Energy and for fulltime research degrees such as ME, MSc and PhD. Each scholarship is valued at around $40,000.

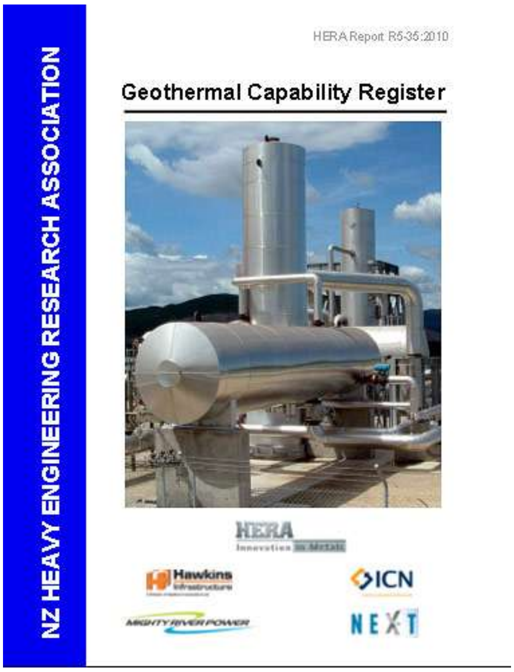
8. Government Statement of Willingness to Share Information

New Zealand is in agreement with the IPGT charter that to the extent that is practicable, the research and design fostered should be open and non-proprietary. The protection and allocation of intellectual property will be subject to the individual agreement and implementing arrangements between participating collaborators.

Appendix 1: New Zealand Geothermal Industry Participants

The New Zealand Heavy Engineering Research Association (HERA) in co-operation with the Industry Capability Network (ICN) produced a partial listing of New Zealand geothermal industry participants in the form of HERA Report R5-35:2010. The register consists largely of HERA member companies who provide consulting, infrastructure and above ground technology services and has been expanded to include also the wider geothermal services community. The report can be downloaded from the HERA website:

http://www.hera.org.nz/Folder?Action=View%20File&Folder_id=139&File=HERA%20Report%20R5-35%202010.pdf



Appendix 2: Summary of the Status of Major Geothermal Projects

The New Zealand geothermal industry has some information on geothermal projects down to the household developments. The following summary focuses on MW-scale developments, including both heat and electricity. It includes: site name and location, MW produced, stage of development, number of wells, well depth, well temperature, flow rate, reservoir capacity, formation details, type of technology (and brand) used, power plant type, current capacity and plan for expansion.

1. Installed Capacity

Project	Location	Operator(s)	Status	MWe
Wairakei Power Station	Wairakei-Tauhara Geothermal Field	Contact Energy	Operating. Flash steam turbines (155MW) & binary cycle (14MW)	171
Kawerau Power Station	Kawerau Geothermal Field	Mighty River Power	Operating. Single steam dual flash turbine (100MW)	100
Ohaaki Power Station	Ohaaki Geothermal Field	Contact Energy	Operating. Flash steam turbine.	55
Kawerau Binary	Kawerau Geothermal Field	Bay of Plenty Energy, Norske Skog, Eastland Group	Operating. Small scale generation (binary, turbo-alternator)	22
Poihipi Power Station	Wairakei-Tauhara Geothermal Field	Contact Energy	Operating. Dry steam turbine	55
Rotokawa Power Station	Rotokawa Geothermal Field	Mighty River Power, Tauhara North 2 Trust	Operating. Steam back pressure turbine & 4 x binary cycle.	34
Ngawha Power Station	Ngawha Geothermal Field	Top Energy	Operating. Binary cycle.	25
Mokai Power Station	Mokai Geothermal Field	Tuaropaki Trust, Mighty River Power	Operating. Steam back pressure turbine & 4 x binary cycle.	113
Te Huka	Tauhara Geothermal Field	Contact Energy	Operating. Binary cycle.	23
Nga Awa Purua	Rotokawa Geothermal Field	Mighty River Power, Tauhara North 2 Trust	Operating. Single shaft triple flash turbine	140
			TOTAL INSTALLED CAPACITY (MW)	**738**

2. Consented Developments

Project	Location	Operator(s)	Status	MWe
Kawerau	Kawerau Geothermal Field	Norske Skog	In development, expansion under existing consents. Construction underway.	25
Te Mihi Power Station	Wairakei-Tauhara Geothermal Field	Contact Energy	In development. Consented to develop field and construct power station. Construction underway.	166
Ngatamariki	Ngatamariki Geothermal Field	Mighty River Power, Tauhara North 2 Trust	In development. Consented to develop field and construct power station.	80
Tauhara II	Wairakei-Tauhara Geothermal Field	Contact Energy	In development. Consented to develop field and construct power station.	250
			TOTAL CONSENTED CAPACITY (MW)	**521**

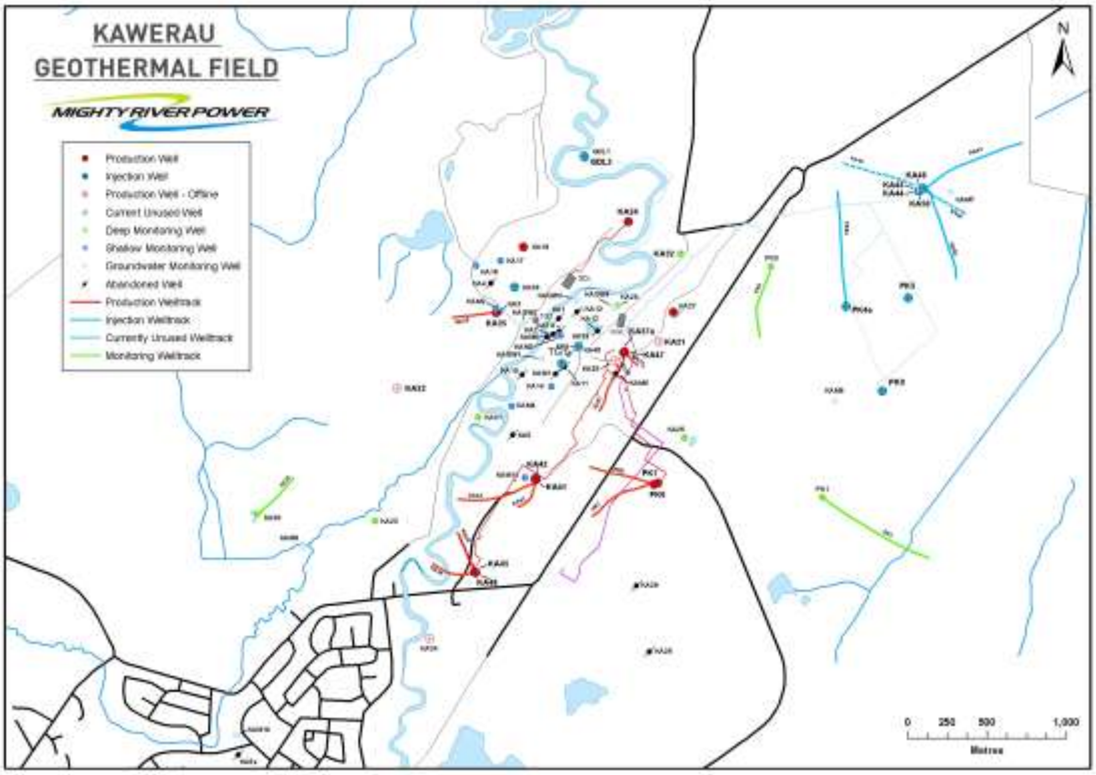
3. Exploration Projects

Project	Location	Operator(s)	Status	MWe
Rotoma	Rotoma Geothermal Field	Rotoma No 1 Inc	Geoscientific assessment & exploratory drilling. Application for consent for 35MW station.	35
Kawerau	Kawerau Geothermal Field	Eastland Group, Kawerau A8D Ahuwhenua Trust& Innovations Development Group	Geoscientific assessment & exploratory drilling. Possible 50MW	50
Tikitere	Tikitere Geothermal Field	Tikitere Trust, Ormat Technologies	Geoscientific assessment & exploratory drilling. Investigating development of 45MW station.	45
Ohinemutu/Ngapuna	Rotorua Geothermal Field	Ngati Whakaue Tribal Lands Trust	Application for consent to develop small scale power plants (~1MW)	1
Taheke	Taheke Geothermal Field	Contact Energy, Taheke 8C Trust	Exploratory drilling. Geoscientific assessment.	50
			ADDITIONAL CAPACITY UNDER EXPLORATION (MW)	**181**

Site Name: Kawerau Geothermal Field

Location: The Kawerau geothermal field is located immediately east of Kawerau township. Most of the surface thermal features are believed to have been in a natural state of decline prior to development, which arose from the energy requirements of the large Tasman pulp and paper processing plant built in the 1950s.

Resource Information:



Resource temperature = 260-305°C

Maximum measured temperature = 310°C

Number of wells:

- KGL Production = 7
- NTGA Production = 5
- GDL Production = 1
- KGL Injection = 5
- NTGA Injection = 3
- GDL Injection = 1
- Other monitoring wells = 24

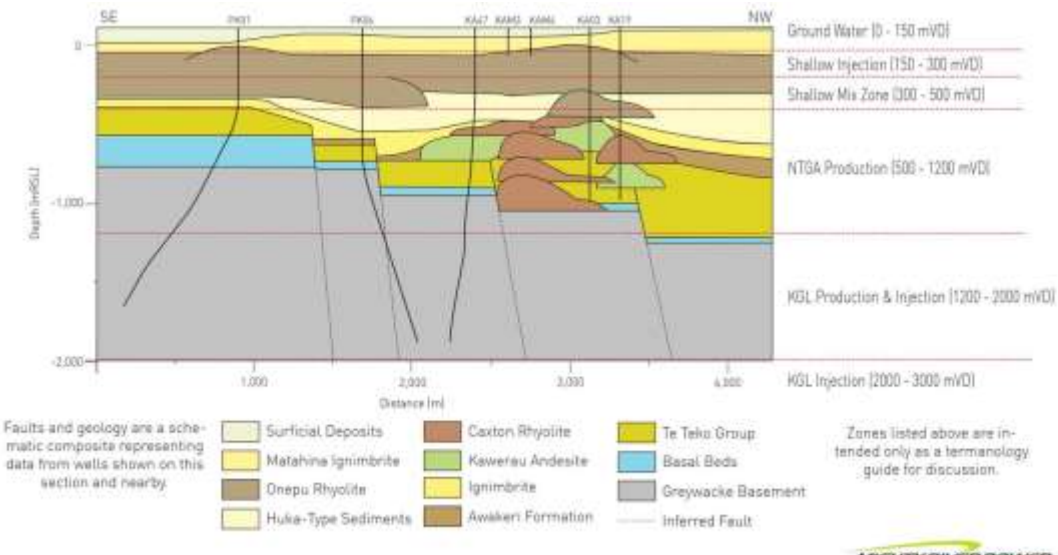
Typical production well depth = 950-2100 m

Typical injection well depth = 300-3000 m

Maximum well depth = 3000 m

Assessed Generating Capacity = 350-570 MWe (Lawless 2002)

Formation Details (from Bignall and Harvey 2005):

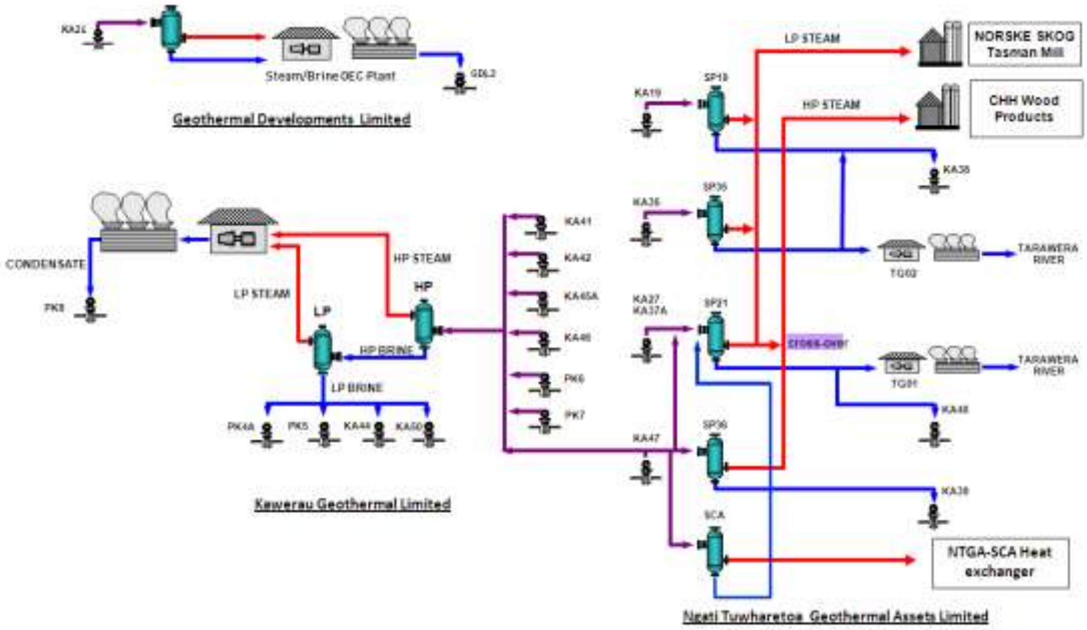


Geothermal fluids originate from fractures in the Mesozoic basement rocks, which are overlain by a sequence of layered volcanic lavas, welded ignimbrites, pyroclastic rocks and lacustrine sediments. Permeable zones are commonly hosted by pyroclastic and fractured lava (rhyolite or andesite) units and within the fractured and/or faulted basement greywacke.

Reinjection Strategy: A combination of shallow infield injection and deep peripheral field reinjection to the north are currently employed on the field. The remaining geothermal fluid is cooled and discharged to the Tarawera river.

Development Details:

Several different companies draw on the Kawerau geothermal resource, as can be seen in Figure 1, below. On the field the geothermal fluid is separated to produce steam for electricity generation and process heat steam is supplied to the Norske Skog Tasman, Carter Holt Harvey and SCA Hygiene operations for the purposes of paper drying, timber drying, and power generation.



Developer	Power Plant	Year commissioned	Type	Total Installed Capacity or equivalent (MWe) Gross	Annual Energy Produced (GWh/year)
Mighty River Power	Kawerau Power Station	2008	Dual flash plant	110	877
Bay of Plenty Electricity	TG1		Binary	3	
Bay of Plenty Electricity	TG2		Binary	4	
Ngati Tuwharetoa Geothermal Assets	Process heat to Norske Skog Tasman and Carter Holt Harvey	1957		65	
Ngati Tuwharetoa Geothermal Assets	SCA Hygiene – Clean Steam Unit	2010		4	
Eastland Energy	Geothermal Developments Ltd	2008	Binary	10	65

Plant Name: Kawerau Power Station

Upstream Developer = Kawerau Geothermal Limited (Mighty River Power)

Downstream Developer = Kawerau Geothermal Limited (Mighty River Power)

Operator = Mighty River Power

Plant Type: dual flash separation

Principal supplier: Sumitomo Corporation and Fuji Electric Systems

High pressure separator = 12 barg

Low pressure separator = 1.9 barg

Total steam flow = 1000 t/h

Brine flow = 1500 t/h

Plant Name: Ngati Tuwharetoa Geothermal Assets Ltd.

Upstream Developer = Ngati Tuwharetoa Geothermal Assets Ltd.

Downstream Developer = Norkse Skog Tasman, Carter Holt Harvey, SCA Hygiene and Bay of Plenty Energy

Operator (upstrm.) = Mighty River Power

Plant Type = single flash separators, bottom end binary units, heat exchanger

Separator pressure = 9-10barg

Total steam flow = 375 t/h

Brine flow = 1570 t/h

Plant Name: Norske Skog Tasman/Carter Holt Harvey

Short description: plant first received steam in 1957. A small geothermal generator was included in the plant in 1966 and was replaced in 2004. Overall the plant receives 300t/h of geothermal steam primarily for process heat purposes.

By itself, this plant accounts for almost half of New Zealand's geothermal direct heat use.

Plant Name: SCA Hygiene

Short description

This is one of the latest heat plants to be commissioned in New Zealand and means that SCA Hygiene's heat supply is from an entirely renewable energy source.

Plant Name: Bay of Plenty Energy Plant – TG1

Short description: This was the first binary cycle plant installed in New Zealand. It takes waste water from the steamfield supply dedicated primarily to the NST heat plant

Plant type = binary

Principal supplier = Ormat

Total water flow = 266 t/h of brine at about 8ba

Plant Name: Bay of Plenty Energy Plant – TG2

Short description: This slightly later binary cycle plant is located on the other side of the Tarawera River and uses further waste water otherwise discharged to the pond seen in the background of the photo of TG1

Plant type = binary

Principal supplier = Ormat

Total water flow = 180-325 t/h of brine at about 8 ba

Plant Name: Geothermal Developments Ltd (also known as KA24 Station)

Upstream Developer (now) = Eastland Energy Ltd

Downstream = Eastland Energy Ltd

Upstream operator = Mighty River Power

Plant type = binary

Principal supplier: Ormat

Total mass flow = 200 t/h

[The following table is taken from Table 2 of Harvey, White, Lawless and Dunstall 2010 – NZ Country Update]

Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Annual Energy Produced (GWh/year)
Tasman BP	1966	1	Retired	1 BP	10	
Tasman BP	2004	1	Operating	1 BP	8	43
TG1	1989	2		B	2.4	8
TG2	1993	1		B	3.5	26
KA24	2008	1		B	8.3	65
Kawerau	2008	1		2F	100	877
NST			Planned	B		
KA22				B		

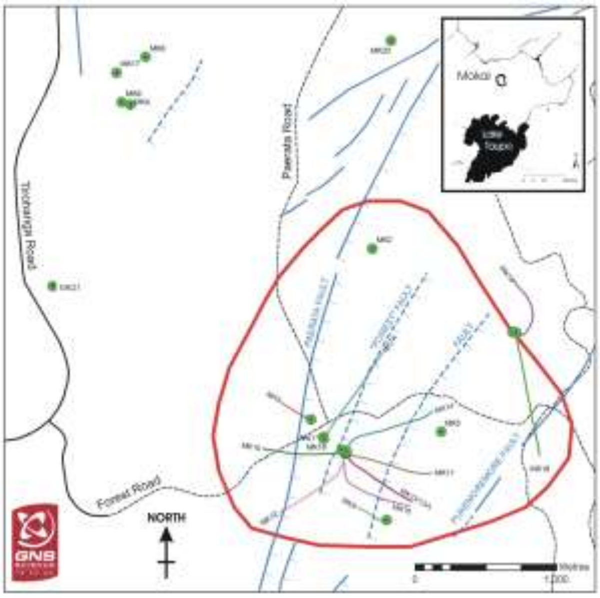
Future Plans for Kawerau Geothermal Field: All current and aspiring developers continue to assess the potential for expansion of the Kawerau Geothermal Field. There is strong demand for additional process heat and electricity generation in the region.

Field Categorisation: For consent purposes the field is categorised as a Development Geothermal System by Bay of Plenty Regional Council so can be developed subject to consents.

Site Name: Mokai Geothermal Field

Location: The Mokai geothermal field is located 20 km north of Taupo, remote from geothermal tourist attractions. The field lacks the spectacular thermal activity present at many other fields, consisting only of small areas of steam-heated activity.

Resource Information (from Lawless):



Resource temperature = 280°C

Maximum measured temperature = 326°C

Number of wells (2011):

Production = 11

Injection = 6

Other = 4

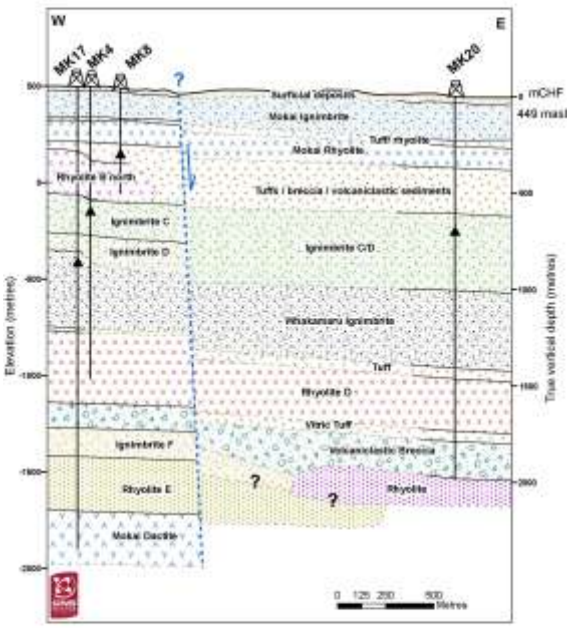
Typical production well depth = 1.5 – 2.6 km

Typical injection well depth = 0.5 – 2.6 km

Maximum well depth = 2.632 km

Assessed Generating Capacity = 140 MWe

Formation Details (from Bignall, Rae and Rosenberg 2010)



Permeable zones are commonly hosted by ignimbrite and fractured lava (rhyolite or andesite) units, even though basement faults are likely to provide deep structural control on the primary fluid upflow.

Reinjection Strategy: 100% reinjection through common reinjection system for all plants at northern periphery of field at a typical depth of 500 to 2400 m.

Development Details

Plant Name: Mokai Power Station (1, 2, 1A) (largest merchant power station in NZ)

Upstream Developer = Tuaropaki Power Company

Downstream Developer = Tuaropaki Power Company

Operator = Mighty River Power

Plant Type: hybrid binary

Principal supplier: Ormat

Flash pressure = 19.5-21 bara

Steam flow = 730 t/h

Brine flow = 605 t/h

[The following table is taken from Table 2 of Harvey, White, Lawless and Dunstall 2010 – NZ Country Update]

Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Annual Energy Produced (GWh/year)
Mokai 1	1999	6	Operating	H (1F, B)	55	927
Mokai 2	2005	5		H (1F, B)	39	
Mokai 1A	2007	1		B	17	

Plant Name: Mokai Glass House

Upstream Developer = Tuaropaki Power Company

Downstream Developer = Gourmet Mokai

Operator (upstrm.) = Mighty River Power

Plant Type = direct use, parallel

Heat usage = 315 TJ/year

Photo is of 5.5 ha glass house prior to its expansion to 11.7 ha

Plant Name: Miraka Whole Milk Powder Plant

Upstream Developer = Tuaropaki Power Company

Downstream = Miraka Limited

Upstream operator = Mighty River Power

Plant type = direct use, parallel

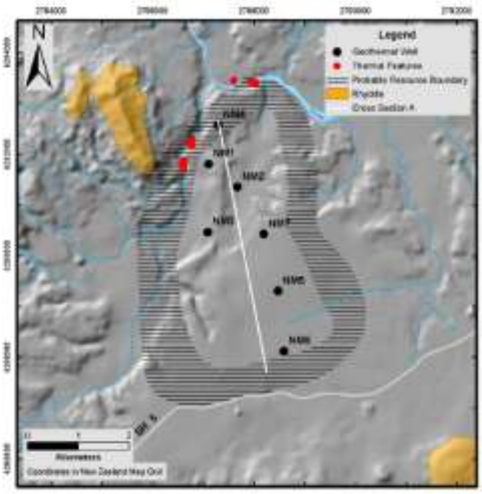
Heat usage = 270 TJ/year (projected)

Status: final commissioning August 2011 (world first geothermally supplied dairy factory)

Future Plans for Mokai Geothermal Field: Tuaropaki Power Company continues to assess the potential of the Mokai Geothermal Field. They recognise the value associated with steam for direct heating purposes. Experiments have been undertaken to clean up the non-condensable gas flow from the cooling towers so the CO_2 can be used in the glasshouse rather than purchasing this externally.

Field Categorisation: For consent purposes the field is categorised as a Development Geothermal System by Waikato Regional Council so can be developed subject to consents.

Site Name: Ngatamariki Geothermal Field



Location: The Ngatamariki geothermal field is located 5 km south of Orakeikorako and 17 km north-east of Taupo. Compared with other geothermal fields, the Ngatamariki field has few surface thermal features and only a small outflow of geothermal fluid. The Ngatamariki Geothermal Development is located within what was the Tahorakuri Forest, bordered by farmland to the east and west, and the Waikato River along the northern and southern boundary.

<u>Resource Information</u> (taken from resource consent application, and Boseley et al WGC 2010):

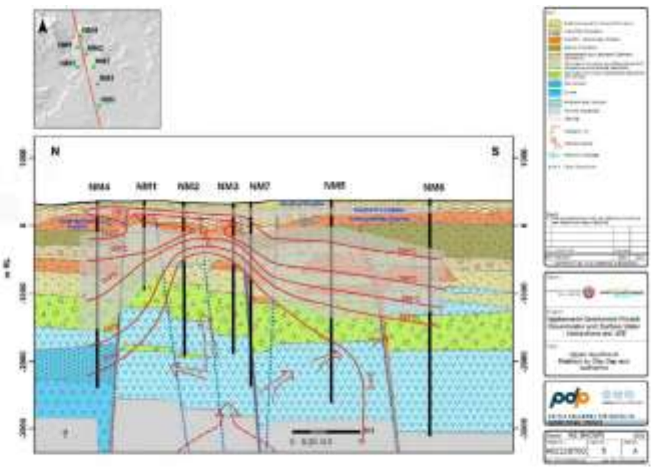
Resource Temperature = 255 – 290 ^{o}C

Maximum well depth = >3 km

Number of wells: there are 8 existing wells and a rig will be mobilising to complete a drilling program in coming weeks

Assessed generating capacity = ~200 MWe

Formation Details:



The geology at Ngatamariki to +200 m RL is dominated by surficial deposits of alluvium, including Orakonui Breccia and Whakapapataringa rhyolite, and lacustrine sediments of the Huka Falls Formation. Underlying the near surface volcanic-sedimentary sequence is crystal-rich tuff and breccias of the regionally-extensive Wairoa Formation, partly welded crystal-lithic Wairakei Ignimbrite, and Akatarewa Ignimbrite and andesite (Tahorakuri Formation). Torlesse greywacke (basement) beneath the andesite layer has been intersected only by NM6 to date. Underlying the andesite lava and breccias in NM4 is a quartz diorite pluton.

Reinjection Strategy: Consents have been obtained for reinjection of fluid.

<u>Development Details</u>:

<u>Plant Name</u>: Ngatamariki Power Station (under construction)

Upstream developer = Rotokawa Joint Venture Ltd

Downstream Developer = Rotokawa Joint Venture Ltd

Operator = Mighty River Power

Plant Type = hybrid binary

Principal supplier = Ormat

Other details to follow construction

Future Plans for Ngatamariki Geothermal Field: The current contract is for the development of a first stage of development. Further use may follow the initial operation.

Field Categorisation: For consent purposes the field is categorised as a Development Geothermal System by Waikato Regional Council so can be developed subject to consents.

Site Name: Ngawha Geothermal Field

Location: The Ngawha geothermal field is located 6 km east of Kaikohe in Northland and is the only high temperature geothermal field outside the Taupo Volcanic Zone. The surface expression of the underground system at Ngawha is small and includes a number of small fossil sinter deposits, two large areas of hydrothermal clay deposits and about 20 hot springs near Ngawha village. The first geothermal power station, Ngawha 1, is situated approximately 1 km south-west of Ngawha village, and the second station is a similar distance south-south-east of the village.

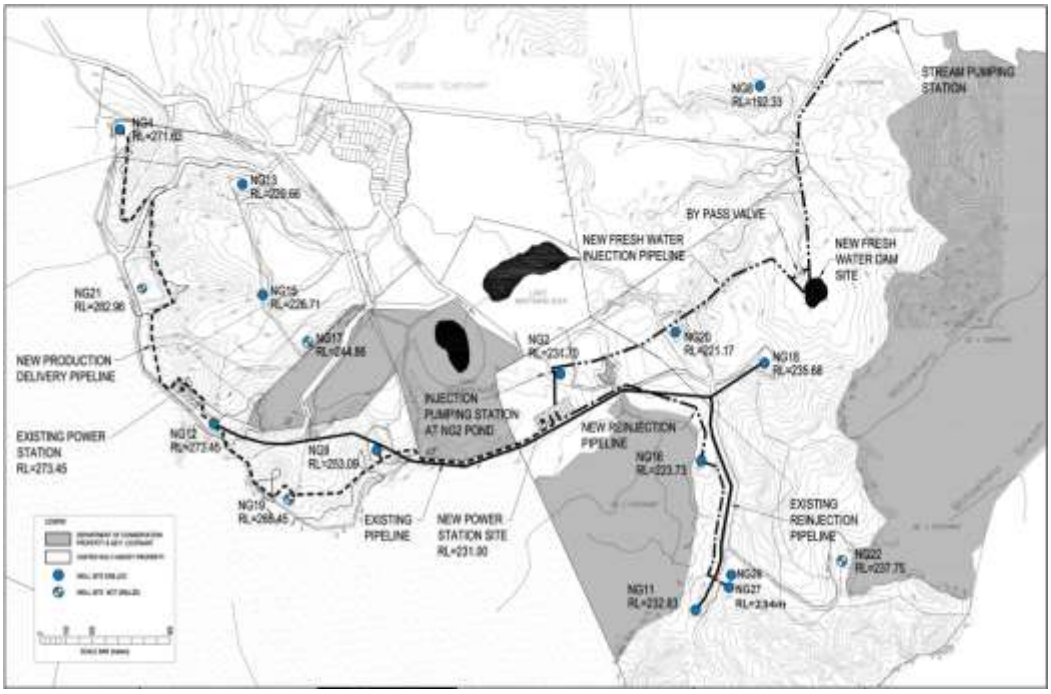


Figure: Ngawha power station and steamfield layout

<u>Resource Information</u>:

Resource temperature = 228^{o}C

Maximum measured temperature = 301^{o}C

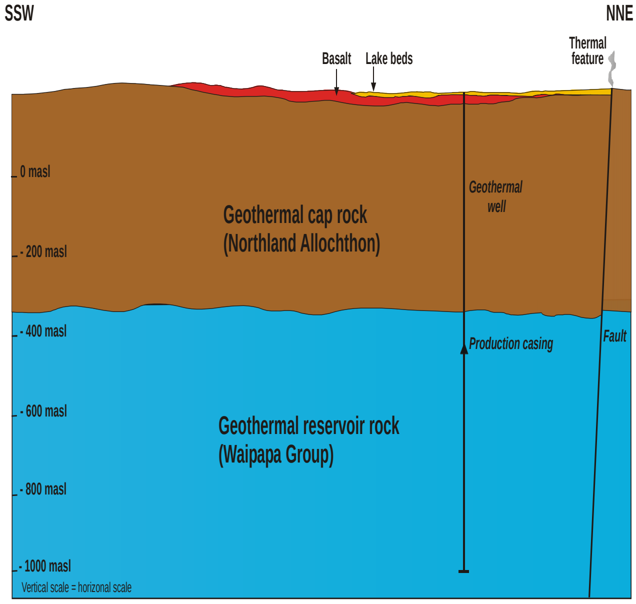
Number of wells (2011):

- Production = 3
- Injection = 5
- Other = 2

Typical well depth = 1 km

Maximum well depth = 2.3 km

Assessed Generating Capacity = 75 MWe (Lawless)



Formation Details: The figure shows a geological cross section with the depth of the geothermal reservoir and a typical deep well shown to true vertical scale. There is a large body of almost impermeable rock (claystone, sandstone, mudstone, and limestone often called the "cap rock", although it does not form a total seal) separating the deep greywacke reservoir from the surface (Lawless 2006). Permeability is fracture-dependent.

Figure: Ngawha reservoir cross-section

Reinjection Strategy: From its inception Ngawha was designed and built to facilitate 100% reinjection. Refinements have enabled emergency shutdown discharges to also be fully injected to avoid any discharge of geothermal fluids to catchment. All re-injection wells are at the periphery of field, and have a typical depth of 1 km. Supplementary injection of freshwater is also available to mitigate any potential reservoir pressure decline.

Development Details

Plant Name: Ngawha Generation Ltd

Upstream Developer: Top Energy Ltd

Downstream Developer: Top Energy Ltd

Operator: Ngawha Generation

Plant Type: Binary

Principal supplier: Ormat

Flash pressure: 11/12 bara

Steam flow: 85 t/h

Brine flow: 950 t/h

The two geothermal power stations at Ngawha are shown in the Figures below.

Figure: Station 1, 10MWe Ormat binary plant commissioned in 1998

Figure: Station 2, 15 MWe Ormat binary plant commissioned in 2008

Current (2011) generation capacity at Ngawha is 25 MWe. A summary of the station capacity, plant type and technology is given in Table 1 below.

Table 1: Summary of station technology, plant type and current capacity

Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Energy Produced (GWh/year)
Ngawha 1	1998	2	Operating	B	10	200
Ngawha 2	2008	1	Operating	B	15	

Future Plans for Ngawha Geothermal Field: After appropriate monitoring, likely to take about 5 years, consideration will be given to whether any future expansion will occur.

Site Name: Ohaaki (Broadlands) Geothermal Field

Location: The Ohaaki-Broadlands geothermal field is located 20 km northeast of Taupo immediately south of State Highway 5.

Resource Information: Refer (WGC 1995 p1797 Operational History of the Ohaaki Geothermal Field, Clotworthy, WGC2000, p3211, Operational History of the Ohaaki Geothermal Field, Lee)

Production reservoir temperature 220-300°C

Number of wells (2010)

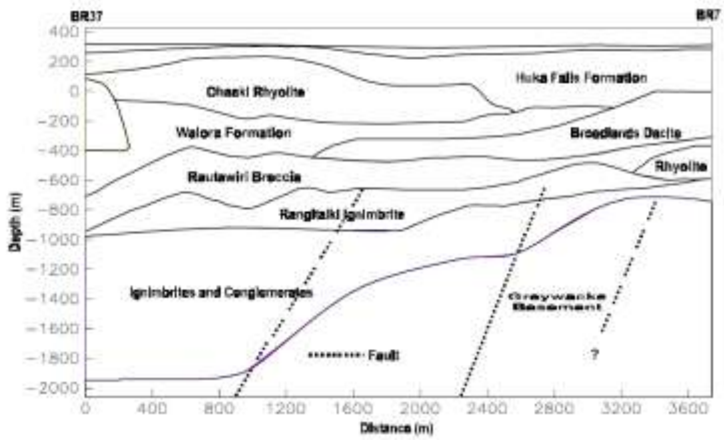
Production = 23

Injection = 6

Production well depth = 1-2.5 km

Assessed Generating Capacity = 130 MWe (but production constraints limited output to 47 MWe in 2010)

Formation Details:



The major stratigraphic units comprise the following:
Huka Falls Formation: a mudstone which acts as a cap over much of the field.
Ohaaki Rhyolite: this lava has high horizontal permeability and is hydraulically connected to groundwater aquifers.
Waiora Formation: the main producing aquifer composed of heterogeneous uncompacted pumice and lapilli tuffs. Lying immediately below the Ohaaki Rhyolite or separated by a thin Huka Falls mudstone layer, it appears to be hydrologically connected to the overlying Ohaaki Rhyolite.
Rautawiri Breccia: the second important aquifer composed of coarse breccias.
Rangitaiki Ignimbrite, Ohakuri Group volcanics and Waiora Formation conglomerates: rocks of poorly known production material
Greywacke: permeability will exist in fractures.

Reinjection Strategy: 60% of produced fluid is injected, mostly through outfield injection. Much of the balance of fluid is lost through the cooling tower. A portion (4-5%) is fed to a kiln operation from which it discharges to previously active surface features then the Waikato River.

Development Details

Plant Name: Ohaaki Power Station

Upstream Developer = Contact Energy

Downstream Developer = Contact Energy

Operator = Contact Energy

Plant Type: double flash using refurbished high pressure back pressure turbines from Wairakei

Principal supplier: various as was designed by DesignPower. Turbines – MHI, generator – Fuji, condenser/gas extraction system – Franco Tosi

Turbine inlet pressure = 10 bara (HP - 2011) and 4.5 bara (IP)

Average production 36 kt/day.

The following table is taken from Table 2 of Harvey, White, Lawless and Dunstall 2010 – NZ Country Update

Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Annual Energy Produced (GWh/year)
Ohaaki	1989	1	Retired	1 HP-BP (ex-Wairakei)	11	
	1989	1	Operating	1 HP-BP (ex-Wairakei	11	410 }
	1989	1		1F	92	

Plant name: Ohaaki Thermal Kilns

Upstream Developer = Contact Energy

Downstream Developer = Vanner

Operator (upstream) = Contact Energy

Plant Type = direct use, cascade

Heat usage = 438 TJ/year

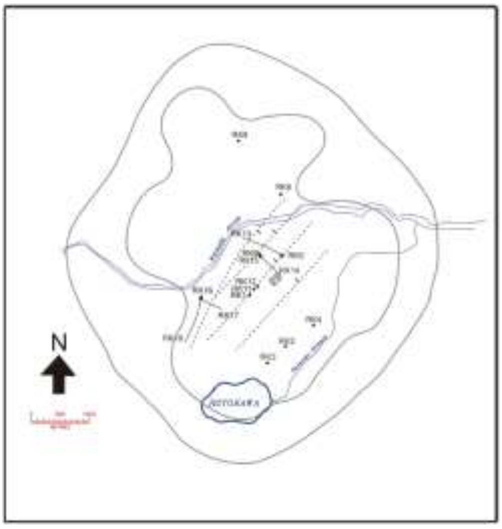
Future Plans for Ohaaki Geothermal Field: Current strategies are focussed on maintaining generation from existing assets.

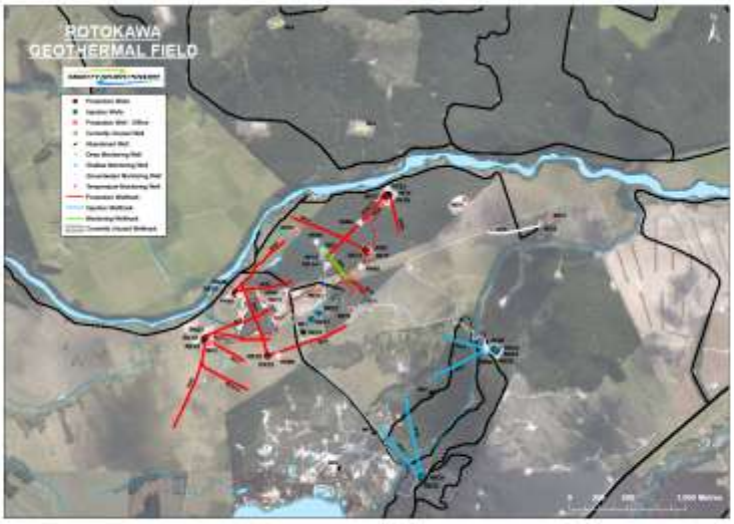
Field Categorisation: For consent purposes the field is categorised as a Development Geothermal System by Waikato Regional Council so can be developed subject to consents.

Site Name: Rotokawa Geothermal Field

Location: The Rotokawa geothermal field is located about 14 km northeast of Taupo and 9 km east of Wairakei. The associated thermal area has extensive surface features including acid-sulphate-chloride springs, neutral-chloride springs, fumaroles, eruption craters and collapse pits. Lake Rotokawa fills one crater, and there are large deposits of sulphur surrounding and beneath the lake.

Resource Information:





Temperature = up to 320 ^{o}C in production wells

In total 30 wells have been drilled at Rotokawa (as of December 2010).

Production depths = 2 – 2.5 km

Injection depths = 2.5 – 3.1 km

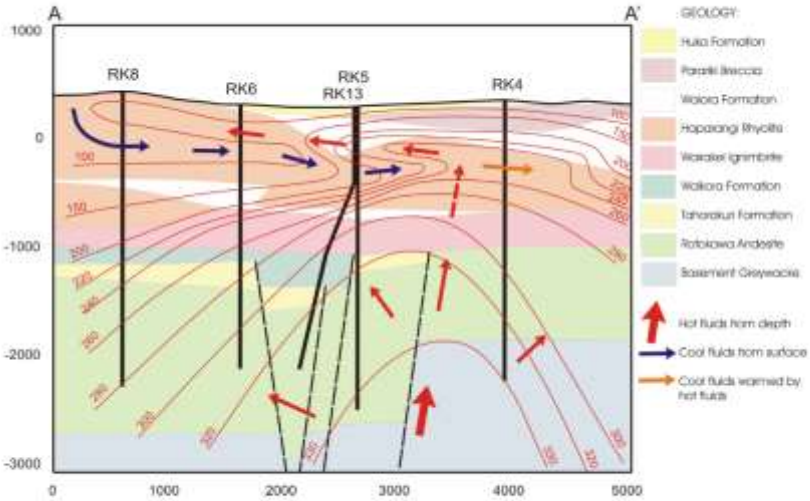
Operating injection wells = 5

Operating production wells = 14

Assessed Generating Capacity = 300 MWe (Lawless 2002)

Formation Details: From Bowyer and Holt, WGC 2010.

The subsurface geology of the Rotokawa Geothermal Field has been interpreted from drill cuttings and cores. Basement Greywacke is overlain by the Rotokawa Andesite, a sequence of andesite lava flows and breccias up to 2000m thick. Differences in the elevation at which the Basement Greywacke and Rotokawa Andesite



are encountered in wells suggest the occurrence of a series of SW-NE striking normal faults, parallel to the structural trend of the Taupo Volcanic Zone, which have resulted in a structural trough (graben) between RK4 and RK6. RK17 is the only well that can be confirmed as having intersected one of these faults.

Overlying the Rotokawa Andesite, and infilling the graben, are the volcaniclastic and sedimentary deposits of the Tahorakuri and Waikora formations (members of the Reporoa Group), which are in turn overlain by the Wairakei Ignimbrite. The elevation of the top of this ignimbrite is relatively constant across the field suggesting no, or very little, reactivation of the graben-forming faults since its deposition. Lack of Wairakei Ignimbrite in RK16-RK18 suggests that the ignimbrite ponded against a fault scarp to the east of these wells. Overlying Wairakei Ignimbrite are the rhyolitic tuffs, ashes and breccias of the Waiora Formation. Haparangi Rhyolite lavas and breccias occur within the Waiora Formation, which is then overlain by mudstones, siltstones and sandstones of the Huka Formation intercalated with the Parariki hydrothermal eruption breccias.

Reinjection Strategy: Initially reinjection was shallow (500 m) partly with a view to protection of production casing from shallow acid fluids. Subsequently injection has been changed to deep targets within the field to the southeast, up to a kilometre away from the production field.

Development Details:

Plant Name: Rotokawa Power Station

Upstream Developer = Rotokawa Joint Venture Ltd (50% Tauhara North No 2 Trust, 50% Mighty River Power)

Downstream Developer = Rotokawa Generation Ltd (100% Mighty River Power)

Operator = Mighty River Power

Plant Type: hybrid binary

Principal Supplier: Ormat

Flash pressure = 25.5 bara (http://www.jardhitafelag.is/media/PDF/S01Paper068.pdf)

Steam flow = 140 t/h

Brine flow = 303 t/h (design)

Plant Name: Nga Awa Purua Power Station

Upstream Developer = Rotokawa Joint Venture Ltd

Downstream Developer = Rotokawa Joint Venture Ltd

Operator = Mighty River Power

Plant Type: triple flash including the world's largest single shaft geothermal turbine (140 MWe)

Principal Supplier: Sumitomo was the EPC contractor while the turbine was from Fuji

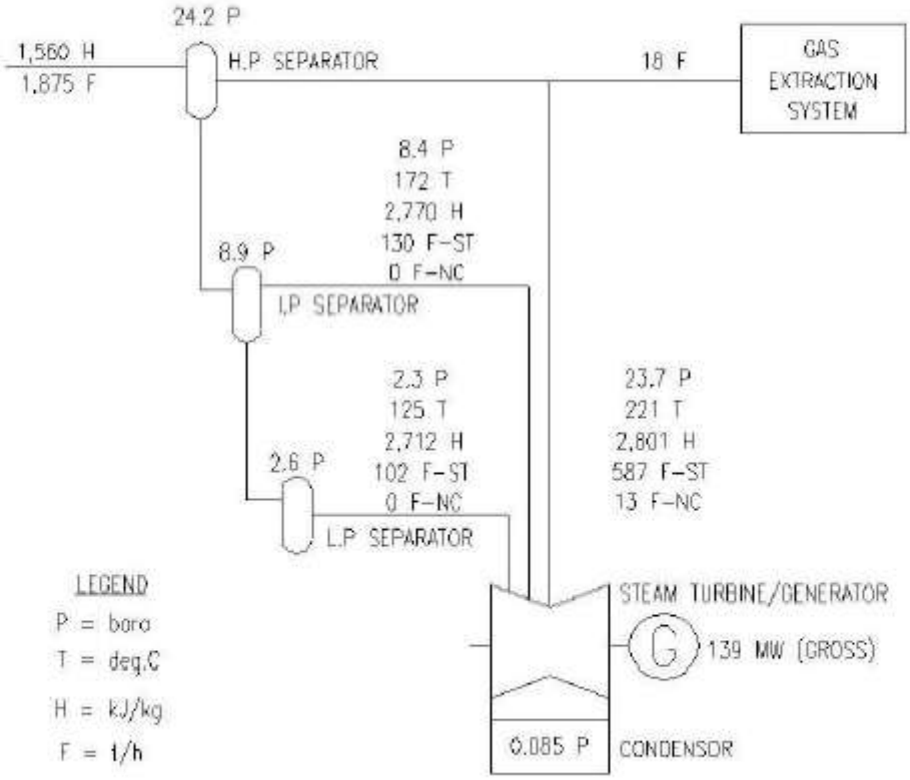


Figure: Triple flash mass and heat balance at design stage (actual output exceeded design) (from Gray, WGC 2010)

The following table is taken from Table 2 of Harvey, White, Lawless and Dunstall 2010 – NZ Country Update

Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Annual Energy Produced (GWh/year)
Rotokawa	1997	4	Operating	H (1F, B)	29	} 273
Rotokawa Extension	2003	1		B	6	
Nga Awa Purua	2010	1		3F	140	1165

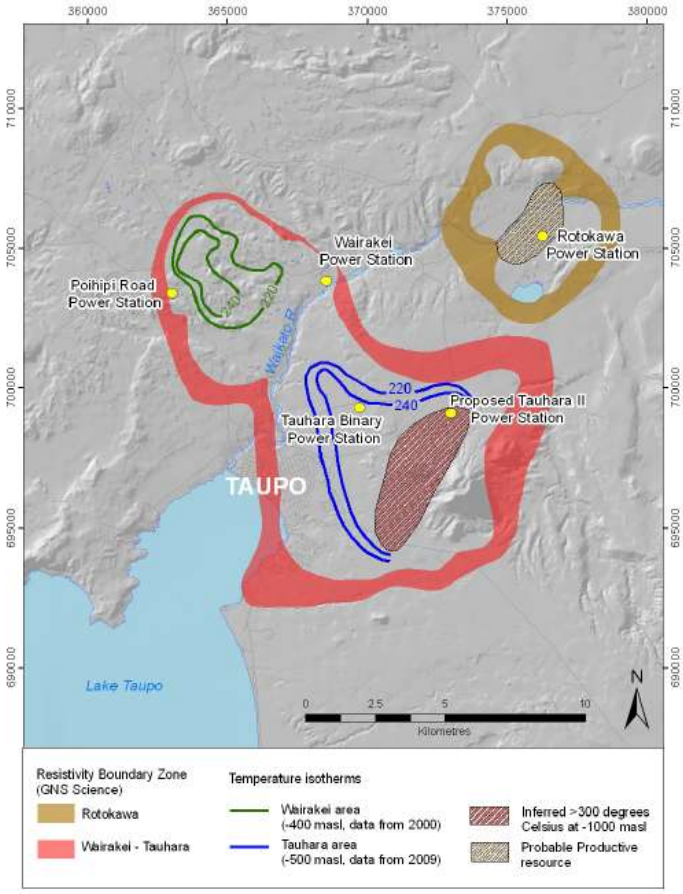
Future Plans for Rotokawa Geothermal Field: The field has a capacity greater than current production. Field response to development is being monitored.

Field Categorisation: For consent purposes the field is categorised as a Development Geothermal System by Waikato Regional Council so can be developed subject to consents.

Site Name: Tauhara Geothermal Field

Location: The Wairakei-Tauhara geothermal system includes the Wairakei geothermal field located 8 km north of Taupo and the Tauhara field to the southeast, with the boundary between the interconnected fields placed at the Waikato River.

Resource Information:



Average temperature in production wells 250°C

Maximum temperature = about 300 °C

Two separate operations at Tauhara: production for power generation and industrial heat supply.

Number of wells (2010):

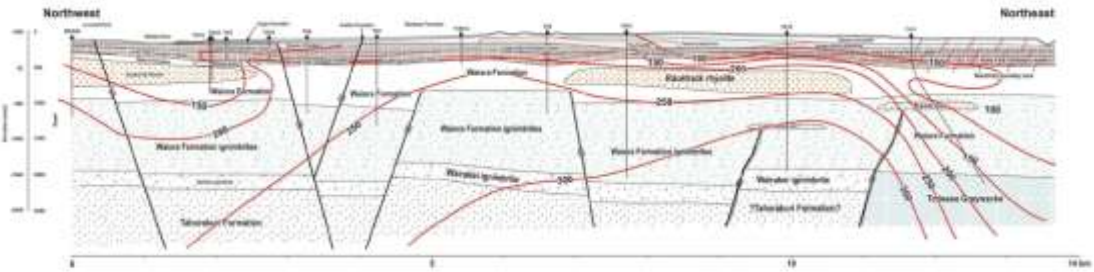
Production = 3

Injection = 3

Typical well depths: production wells 1100m deep and injection 400-1200m.

Assessed Generating Capacity: recent numerical reservoir simulation has shown that >250 MWe is sustainable

Formation Details: (from Tauhara II Consent Application)



Greywacke basement – these ancient marine meta-sediments have been intersected in well TH17 at a depth of 2 km and will be found at increasing depths towards the NW of the field due to the rifting environment. Fluid flow will be through fractures.

Tahorakuri Formation, Wairakei Ignimbrite and Waiora Formation – these are a series of ignimbrites and rhyolites, interspersed with other rhyolite and andesite units. The Waiora Formation, in particular hosts a major geothermal production aquifer in the Wairakei-Tauhara Geothermal System.

Huka Falls Formation – this consists of Upper, Middle and Lower units which in combination help to act as a leaky cap to the system and, while variable in thickness, extend to depths down to sea level.

Oruanui Formation and Recent alluvium and tephra – these are relatively shallow yopug strata that can host groundwaters and some hot water tapped by shallow bores I Taupo township.

Reinjection Strategy: 100% injection at field margin

Development Details

Plant Name: Te Huka Power Station

Upstream Developer = Contact Energy

Downstream Developer = Contact Energy

Operator = Contact Energy

Plant Type: binary

Principal supplier: Ormat

Flash pressure = 9 barg

Steam flow = ~150 t/h

Brine flow = ~750 t/h

In 2010 total fluid extraction averaged 18 kt/d

Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Annual Energy Produced (GWh/year)
Te Huka Tauhara II	2010	1	Operating	B	24	191 est

Plant Name: Tenon Kilns

Upstream Developer = Contact Energy

Downstream Developer = Tenon (wood processing company)

Operator (upstream) = Contact Energy

Plant Type = direct use, parallel

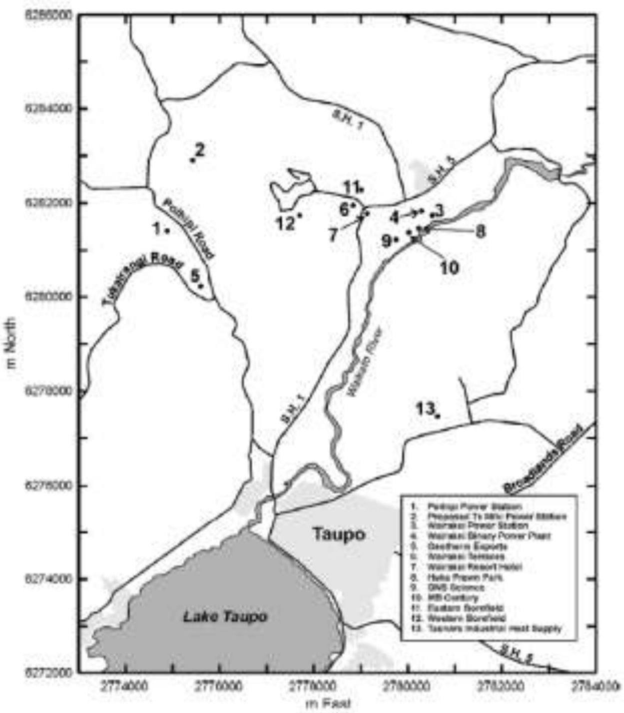
Heat usage = about 1300 GJ/day (about 430 TJ/year)

Future Plans for Tauhara Geothermal Field: Contact Energy has been granted a consent (license) to generate up to an additional 250MWe at Tauhara (the Tauhara II Power Station). At the present time the project is being progressed to enable construction to commence when market conditions are favourable.

Field Categorisation: For consent purposes the field is categorised as a Development Geothermal System by Waikato Regional Council so can be developed subject to consents.

Site Name: Wairakei Geothermal Field

Location: The Wairakei-Tauhara geothermal system includes the Wairakei geothermal field located 8 km north of Taupo and the Tauhara field to the southeast, with the boundary between the interconnected fields placed at the Waikato River. The Wairakei field is exploited by the Wairakei, Poihipi Road and Wairakei Binary power stations. Initially attention was drawn to the field by extensive surface manifestations including a geyser valley. The field has been extensively developed since the early 1950's. 50 years of power generation at Wairakei was celebrated in 2008. Wairakei field is managed by Contact Energy who operate three generating plants and supply heat for space heating in a nearby hotel and offices, to a freshwater prawn farming operation and to a separate tourism operation.



<u>Resource Information</u> (refer Geothermics Special Issue 2009)

Production temperatures = 230-255°C

Number of wells (2010):

Production = 53

Injection = 6

Well depth range = 0.3 – 2.4 km

Assessed Generating Capacity (Lawless) = 510 MWe (reservoir modelling shows currently planned generation is sustainable)

Formation Details: (see earlier details for Tauhara)

Reinjection Strategy: Currently approximately 30% of total extraction (6000 t/h in 2010) is injected/reinjected focussed in peripheral parts of the reservoir.

Development Details

Current total installed plant on the field is approximately 220 MWe in three power plants (original station 157 MWe, Poihipi station 55 MWe and binary plant using 130°C separated geothermal brine, 15 MWe). Average generation in 2010 was 210 MWe net.

Plant Name: Wairakei Power Station

Upstream Developer = (now) Contact Energy

Downstream Developer = (now) Contact Energy

Operator = Contact Energy

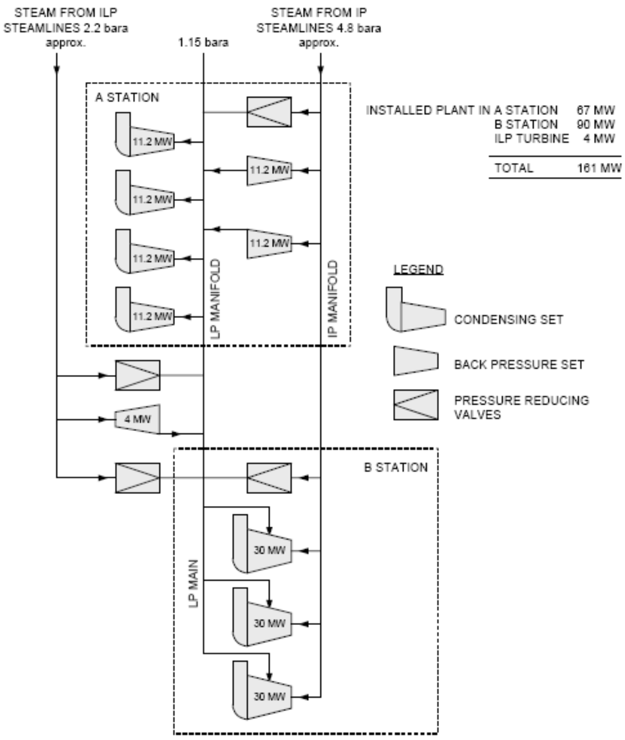
Plant Type: originally triple flash but now double flash with once through river water cooling

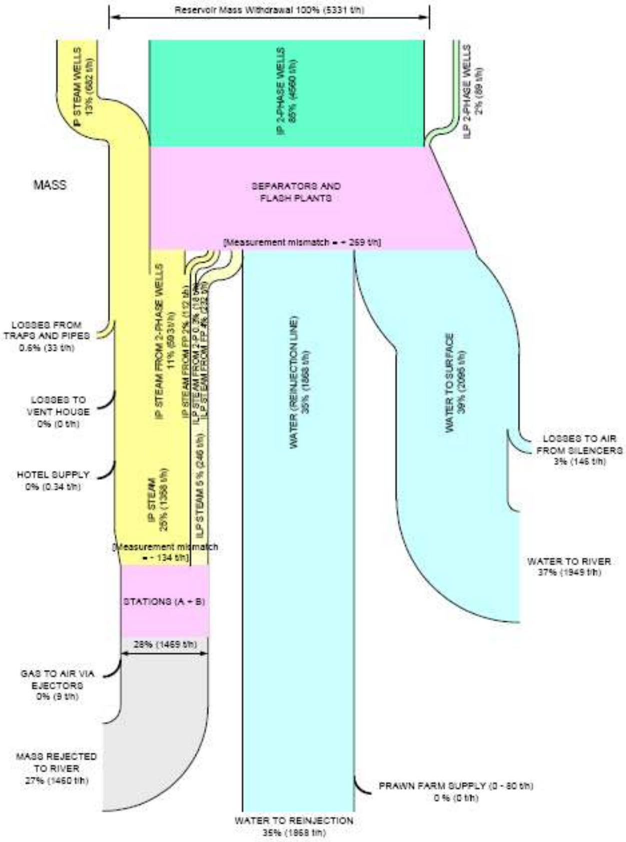
Principal suppliers: various

Pressures and flows – see diagrams below from a report dated 2000

IP steam currently 1250 t/h

For 2010 total fluid extraction averaged 150 kt/day





<u>Plant Name</u>: Wairakei Binary Power Station

Upstream Developer = Contact Energy

Downstream Developer = Contact Energy

Operator = Contact Energy

Plant Type: binary (uses brine from reinjection system)

Principal supplier: Ormat

Brine flow = see reinjection line flow in figure above

<u>Plant Name</u>: Poihipi Power Station

Upstream Developer = (now) Contact Energy

Downstream Developer = (originally Mercury Geotherm) now Contact Energy

Plant Type: dry steam condensing plant

Principal supplier: Fuji

Steam pressure = ~3.5 barg

Steam flow = ~340 t/h for ~43 MWe output – load limited by consents but typically between 35 and 50 MWe now

Power Plant Name	Year Commissioned	No of Units	Status	Type of Unit	Total Installed Capacity (MWe)	Annual Energy Produced (GWh/year)
Wairakei		4	Retired	4 HP-BP	36	
	1958-63		Operating	2 IP-BP		
		9		4 LP-C	157	1249
				3 MP-C		
	1996	1		1 LP-BP	5	
Wairakei Binary	2005	3		B	14.4	118
Poihipi	1996	1		D	55	362
Te Mihi						
Geotherm						

<u>Plant Name</u>: NETCOR Tourism Facility

Upstream Developer = Contact Energy

Downstream Developer = NETCOR

Operator (upstream) = Contact Energy

Plant Type = direct use, cascade (discharges brine over artificial silica terraces before discharge to a stream and the Waikato River – part of a wider tourism facility)

Heat Usage = 820 TJ/year

Plant Name: Wairakei Prawn Farm

Upstream Developer = Contact Energy

Downstream Developer = Wairakei Prawn farm

Operator (upstream) = Contact Energy

Plant Type = direct use, cascade (discharges brine through heat exchangers before discharge to a stream and the Waikato River)

Heat Usage = 270 TJ/year

Future Plans for Wairakei Geothermal Field: Contact Energy has been granted a consent (license) to generate up to 250MWe at Te Mihi, as an intended replacement for the existing Wairakei station. Construction of a first stage 166 MWe Te Mihi power plant is presently under way and scheduled to be commissioned in 2013. This will result in a net 110 MWe increase as some of the existing Wairakei plant will be retired when the new plant is commissioned. Elements of the historic Wairakei station will continue to operate until consents expire, by which time an expanded Te Mihi plant will be operational.

Field Categorisation: For consent purposes the field is categorised as a Development Geothermal System by Waikato Regional Council so can be developed subject to consents.

Appendix 3: Brief Outline of Specific R&D Projects

The following information is given for each project: detailed project description, investment sources and amounts (some of this is confidential), involved parties and industry partners, timeline, and the current status and stage of each project.

1. High Temperature Tools	
Project Name: Wireline logging, acoustic borehole imaging, borehole seismic project *Project Description*: Utilisation of hot, deep geothermal resources is requiring assessment of rock, fluid and reservoir behaviour. Wireline logging and acoustic borehole imaging tools have been developed, and are being used by the geothermal industry in NZ and overseas. Acoustic borehole imaging has been used in NZ since ca. 2009, and AFIT tools are currently being used by both MRP and Contact Energy, with AFIT acquisition and interpretation being undertaken by Tiger Energy Services and GNS Science respectively. This project is developing the interpretive techniques and human capability in a range of wire line logging applications, and advancing acoustic borehole image interpretation capability. A 260°C borehole seismic sensor is in the early stages of being developed in collaboration by the University of Auckland and Geospace, a US based seismic sensor manufacturer	*Involved Parties*: GNS Science, University of Auckland *Industry partners*: Tiger Energy Services, MRP, Contact, Geospace *Investment sources*: MSI, Royal Society of NZ, Tiger Energy Services, Contact, MRP *Amount*: $180k pa *Timeline*: 2009 - ongoing *Status/Stage*: advanced
Project Name: Testing high temperature tools in NZ geothermal fields *Project Description*: Collaborative development of new and improved high temperature tools. Field testing of tools developed in Europe/US (e.g. ISOR) in wells in New Zealand geothermal fields. Development of high temperature electronics to enable mircoresistivity imaging to be used in geothermal wells to improve available wellbore information. Development and evaluation of full-wave sonic techniques for use in geothermal environments. Once past laboratory tests, opportunities to test the high temperature 260°C borehole seismometer will be sought in both NZ and internationally.	*Involved Parties*: GNS Science, IRL, University of Auckland, Tiger Energy Services *Industry partners*: MRP, Contact Energy *Investment sources*: MSI, ICDP, US partners, Contact, MRP *Amount*: $180k pa *Timeline*: 2012+ *Status/Stage*: planned
2. Lower Cost Drilling	
Project Name: Reducing geothermal drilling costs	*Involved Parties*: GNS Science

Project Description:. The NZ geothermal industry have been testing a range of alternative drilling techniques and methodologies, such as PDC drill bits, downhole motors and air drilling. Project to be developed in future. The geothermal drillers and operators would need to agree to release this information.	*Industry partners*: MRP, Contact Energy, MB Century, Parker Drilling *Investment sources*: Industry *Amount*: $1m pa *Timeline*: 2003 - ongoing *Status/Stage*: ongoing
3. Induced Seismicity	
Project Name: Location and characterisation of induced seismicity *Project Description*: Monitoring of seismic networks to develop more accurate techniques for locating and characterising micro-seismic events. Surface and down-hole seismic networks are being monitored at producing TVZ geothermal fields, to locate and characterise induced seismicity, as well as to assist in reservoir fracture characterisation and reservoir monitoring. The project involves data collection, processing and interpretation. Two EGS stimulation projects, one in Australia and the other in the US, have been monitored in 2011, with a third US project to test stimulation monitoring technology scheduled for the end of this year	*Involved Parties*: GNS Science, University of Auckland *Industry partners*: MRP, Petratherm, NakNek Electric, Pioneer Natural Resources *Investment sources*: MSI, MRP, Contact Energy, Royal Society of NZ, Petratherm, Naknek Electric, Pioneer Natural Resources *Amount*: $270k pa plus 245k in 2011 *Timeline*: 2007-ongoing *Status/Stage*: advanced
Project Name: Source parameters and mechanisms *Project Description*: Investigating the cause and effects of induced seismicity. Comparison with overseas studies through the IEA-GIA collaboration, to understand inducing mechanisms (temperature or pressure changes from fluid movement on fractures) under different tectonic stress conditions. Investigation of stress triggers (thermal and/or hydraulic/pressure) and comparison with	*Involved Parties*: GNS Science *Industry partners*: Contact Energy, MRP *Investment sources*: MSI *Amount*: $100k pa

natural seismicity. Testing of risk management strategies to minimise the risk of large induced earthquakes. This is an expected growth area.	*Timeline*: 2007 - ongoing *Status/Stage*: ongoing
Project Name: Long term seismic behaviour in an EGS setting *Project Description*: Determination of the long-term seismic behaviour of an exploited, deep geothermal system. Location and characterisation of microearthquakes. Understanding of risk profiles.	*Involved Parties*: GNS Science, University of Auckland *Industry partners*: MRP, Contact Energy *Investment sources*: MSI, MRP, Contact *Amount*: $150k pa *Timeline*: 2014+ *Status/Stage*: planned
4. Stimulation Procedures	
Project Name: Determination of rock properties & rock property capability testing *Project Description*: Establishment of high temperature physical and deformation rock analysis capability relevant to high temperature geothermal environments. The ability to obtain this rock properties information from geothermal samples will assist in: • rock fracturing to create geothermal resources • permeability development and maintenance • improved well design and well drilling processes • development of geomechanical models Collaborators: Technical U. Darmstadt (Germany), U. Liverpool (UK), University of Bochum (Germany)	*Involved Parties*: GNS Science, University of Canterbury, University of Auckland *Industry partners*: Developing *Investment sources*: MSI *Amount*: $175k pa *Timeline*: 2011 - ongoing *Status/Stage*: commenced
5. Exploration Technologies	
Project Name: Fracture characterisation *Project Description*: Characterisation of deep geothermal reservoir fractures and water / steam flow	*Involved Parties*: GNS Science, University of Auckland, IRL

within them, to better understand their role in focusing hydrothermal fluid, and to establish a combined fluid flow-rock mechanics model of the TVZ. Activities include rheological and hydrothermal alteration studies, rock property testing and borehole imaging, and fracture & fluid flow modelling (TOUGH2, ABAQUS, and SUTRA simulations). Continuing work in combined collection, analysis, and interpretation of geophysical data. Collaborators: Technical U. Darmstadt (Germany), U. Liverpool (UK)	*Industry partners*: MRP, Contact Energy, Refraction Technology *Investment sources*: MSI, Contact, MRP, Royal Society of NZ *Amount*: \$500k pa + in-kind support *Timeline*: 2009-ongoing *Status/Stage*: advanced
Project Name: Deep resource delineation in the TVZ *Project Description*: Application of combined geophysical methods (MT, seismic, gravity and magnetics) to identify heat sources, areas of possible deep-seated permeability and fluid flow, to understand time-spatial changes to fields, and to identify potential targets for future deep drilling. Collection and analysis of MT and seismic data to determine MT and seismic properties in the mid-crust. Development of combined MT-seismic model of physical rock properties. Revision of TVZ basement structure from regional gravity and acquired aeromagnetic data.	*Involved Parties*: GNS Science, University of Auckland *Industry partners*: MRP, Contact Energy *Investment sources*: MSI, Contact, MRP *Amount*: \$600k pa + in-kind support *Timeline*: 2007-ongoing *Status/Stage*: advanced
Project Name: Fluid-rock interactions *Project Description*: Integrated field and laboratory research to assess changes in rock porosity, fracture permeability, well productivity and infrastructure resulting from fluid-rock interactions at high pressures and temperatures (near-critical and supercritical conditions), providing insights into the nature of fluids that may be encountered by future TVZ deep drilling. Delineation of deep stratigraphy and structure of geothermal fields, including updating of 3D geological field models and development of an integrated 4D geological and structural model of the TVZ to 3-7 km depth. Collaborators include: IDDP, Oxford and Open Universities (UK), US Geological Survey, and GeoForschungsZentrum Potsdam (Germany).	*Involved Parties*: GNS Science, University of Auckland, Victoria University of Wellington *Industry partners*: MRP, Contact Energy *Investment sources*: MSI, Contact, MRP *Amount*: \$500k pa + in-kind support *Timeline*: 2008 - ongoing *Status/Stage*: advanced

6. Modelling	
Project Name: TOUGH2 Geothermal reservoir modelling; SUTRA flow in complex rock modelling *Project Description*: Development of improved TOUGH-2 reservoir models for TVZ geothermal fields, incorporating data from chemistry, geology, geophysics and reservoir engineering. Includes well log based rock characteristics in SUTRA, with further development of rock elasticity and responses to temperature and flow changes. Recent advances include: • Coupling of TOUGH2 models to other models, e.g. rock properties models. • Deeper models – increasing supercritical conditions, and decreasing permeability • Larger models (spatially) – regional models rather than just resource focussed model development • Automated calibration of geothermal models using inverse modelling (iTOUGH2 and PEST) and statistical sampling using Markov chain Monte Carlo methods (MCMC) • EGS production in complex natural fractured rock • Modelling of geophysical exploration techniques in complex fracture rock	*Involved Parties*: University of Auckland, IRL, GNS Science *Industry partners*: MRP, Contact Energy, Energy Development Corporation (Philippines); EXXONMobil *Investment sources*: MSI, Contact *Amount*: $350k pa *Timeline*: 2007-2015 *Status/Stage*: advanced
Project Name: Leapfrog Geothermal - 3D Geological Modelling *Project Description*: Development of innovative 3D modelling and visualisation software designed specifically for the geothermal industry. This tool creates comprehensive models of geology including stratigraphy and structures, rock properties and reservoir parameters. Training courses in using the software are also being developed for researchers and industry.	*Involved Parties*: GNS Science, ARANZ Geo *Industry partners*: Contact Energy, MRP *Investment sources*: MSI, ARANZ, MRP, Contact Energy *Amount*: $100k pa *Timeline*: 2009 - ongoing *Status/Stage*: well advanced

7. Other	
Project Name: Cements for Extreme Environments _Project Description_: Development of new cement systems that will perform effectively in high pressure, high temperature and chemically corrosive geothermal conditions.	_Involved Parties_: IRL, GNS Science _Industry partners_: MRP _Investment sources_: MSI _Amount_: $800k pa (MSI contribution) _Timeline_: 2009-2013 _Status/Stage_: advanced
Project Name: Low Enthalpy Geothermal _Project Description_: Developing a programme to increase the uptake of ground sourced and geothermal energy in New Zealand. Work involves technology evaluation, development of technology best practise guidelines, social science and Maori research, resource quantification, development of geophysical techniques and development of material suitable for introduction into the NZ planning framework.	_Involved Parties_: GNS Science, CRL, _Industry partners_: Bosch, Next Energy, Contact Energy, EECA. _Investment sources_: MSI _Amount_: $700k pa _Timeline_: 2009 - ongoing _Status/Stage_: advancing